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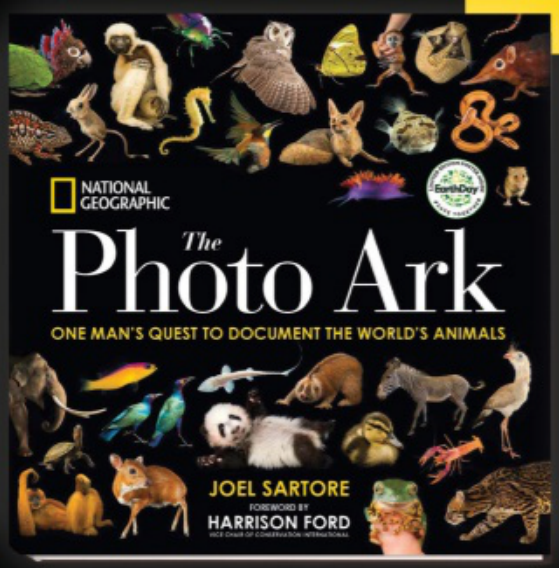

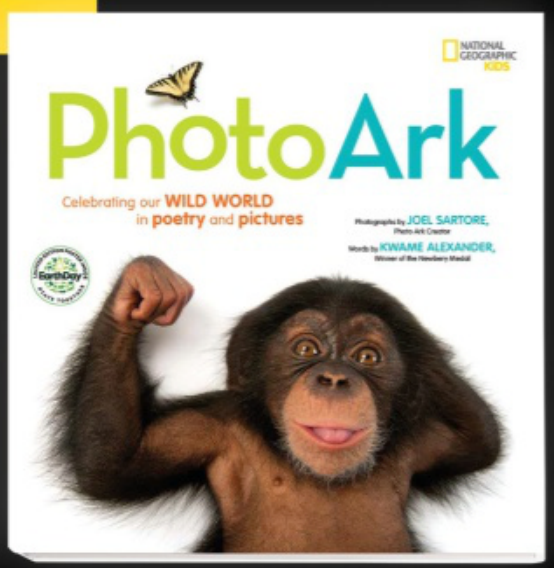
NATIONAL GEOGRAPHIC KIDS
PhotoArk
Celebrating our WILD WORLD in poetry and pictures
Photographs by JOEL SARTORE, Photo Ark Creator
Words by KWAME ALEXANDER, Winner of the Newbery Medal

FOR MANY OF EARTH'S CREATURES, TIME IS RUNNING OUT.

Joel Sartore, founder of the Photo Ark, pledged to photograph every animal species in captivity and inspire people to care and take action. Filled with stunning and exquisite photographs, these books gloriously showcase the infinite variety of the animal kingdom and convey a powerful message with humor, poetry, compassion, and art.

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NATIONAL GEOGRAPHIC

A Pessimist's Guide to Life on Earth in 2070

HOW WE LOST THE PLANET

+

HOW WE SAVED THE WORLD

An Optimist's Guide to Life on Earth in 2070

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SUBARU

EARTH DAY 2070

WHAT LIES AHEAD FOR THE PLANET?

BY SUSAN GOLDBERG

THE SAYING IS SO WELL KNOWN that most of us can finish the sentence: *Those who cannot remember the past…*

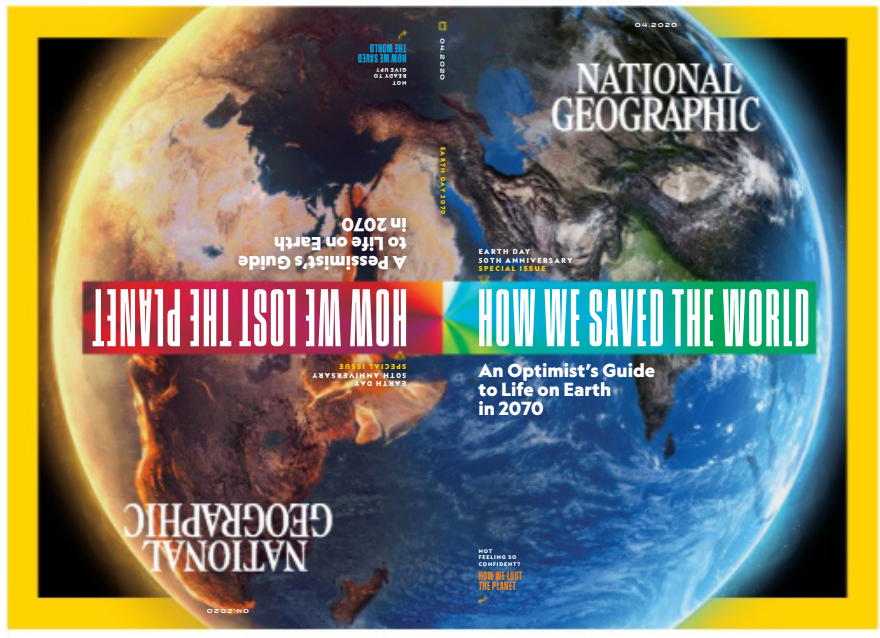
…are condemned to repeat it.

It's a fitting reminder this month as we mark the 50th anniversary of Earth Day. For the occasion, we've created the first ever "flip" issue of *National Geographic*—essentially two magazines in one—to revisit environmental milestones of the past half century and to look ahead at the world our descendants will inhabit in 2070, on Earth Day's 100th anniversary.

Two scenarios emerge.

On the magazine cover just before this page, there's a verdant Earth. Welcome to the optimistic view of writer Emma Marris, who sees a world that is changed—we cannot undo some damage we have done—but one in which technologies will be harnessed to "feed a larger population, provide energy for all, begin to reverse climate change, and prevent most extinctions," Marris writes. "The public desire for action is bursting forth on the streets … Just as in 1970, the electric crackle of cultural change is once again in the air. I believe we will build a good 2070."

Next, turn the magazine over, to the side with the browner Earth. Elizabeth Kolbert looks to a new normal of "sunny-day flooding," when high tide will send water gushing across low-lying U.S. coastal cities, and most atolls will be uninhabitable. This is the world of longer droughts, deadlier heat waves, fiercer storms, and more. "I could go on and on listing the dangerous impacts of climate change," Kolbert writes, "but then you might stop reading." She sees no evidence that we will address those and other threats fast enough to keep them from overwhelming us and the natural world.


NATIONAL GEOGRAPHIC
HOW WE SAVED THE WORLD
An Optimist's Guide to Life on Earth in 2070
HOW WE LOST THE PLANET
A Pessimist's Guide to Life on Earth in 2070
EARTH DAY 50TH ANNIVERSARY SPECIAL ISSUE

It's impossible to know who is right. The stories in this issue reflect divergent realities. When I read about the young people taking charge of the environmental movement, I feel buoyed. Then I see Pete Muller's photos of a scarred landscape we will never get back. What I do know is that it is our job to provide a factual framework for what is happening, documentary photography about what is forever changed and what we can save, and information to help empower all of us to make a difference.

Thank you for reading *National Geographic*.

Snares Penguin
(Eudyptes robustus)

Size:
Body length, 56 - 73 cm (22 - 28.7 inches)
Weight:
2.4 - 4.3 kg (5.3 - 9.5 lbs)
Habitat:
Breeds only on the Snares Islands
Surviving number:
Estimated at 63,000 mature individuals

Photographed by Mark MacEwen

WILDLIFE AS CANON SEES IT

All together now. The Snares penguin is so in tune with its breeding colony – typically 50 to 500 pairs, but occasionally over 1,000 – that its nesting patterns are synchronized to within a week. The same pairs reunite at the same breeding sites every year, with the female laying two eggs and only the stronger chick generally surviving. But today's young are being brought into an increasingly hostile world, with perils ranging from oil spills to the reduction of prey due to commercial fishing and ocean warming.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.

Canon

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SINCE OUR FOUNDING IN 1888, NATIONAL GEOGRAPHIC HAS BEEN WORKING TO CONSERVE THE PLANET AND ITS INHABITANTS. THIS MONTH, ALONG WITH THE WALT DISNEY COMPANY (THE MAJORITY OWNER OF NATIONAL GEOGRAPHIC PARTNERS), WE'RE CELEBRATING EARTH DAY'S 50TH ANNIVERSARY WITH MULTIMEDIA STORYTELLING AND EVENTS, AS WELL AS SPECIAL PROGRAMMING ON NATIONAL GEOGRAPHIC, ABC, AND DISNEY+.

CALL TO ACTION

#NatGeoSaveTogether Help protect wildlife

Join National Geographic and Disney as we focus on saving 50 of the planet's at-risk species. Find out how you can help, beginning April 1 at *nationalgeographic.com*.

LIVE TV SPECIAL

Born Wild and ready to explore

How better to appreciate Mother Earth than by meeting her offspring? A live celebration of animal babies, *Born Wild: Earth Day Live* airs April 22 at 8/7c on National Geographic and Nat Geo WILD.

NAT GEO TV

Take inspiration from *Jane: The Hope*

Join Jane Goodall as she travels the world, calling us all to activism on behalf of wildlife and the planet. *Jane Goodall: The Hope* premieres April 22 at 9/8c on National Geographic and Nat Geo WILD.

NAT GEO KIDS

Show children how to 'Save the Animals'

For Earth Day, *Nat Geo Kids* magazine explains how people saved once threatened species, then shows young readers how they can help. Find more articles, photos, and a quiz at *natgeokids.com*.

ANIMAL KINGDOM

Celebrate Earth Day at a theme park

Nat Geo explorers share their stories at Disney's Animal Kingdom April 18-22. Among them: photographer Joel Sartore, whose Photo Ark project raises awareness of animal extinction.

NAT GEO LIVE

Explore big cats with our photographer

Attend *Nat Geo Live* events, coming to a venue near you. This month, track tigers, jaguars, and more with veteran photographer Steve Winter. Find an event at *nationalgeographic.com/events*.

NAT GEO BOOKS

For Earth Day, savor U.S. national parks

National Geographic's *Atlas of the National Parks* showcases these natural treasures through photographs, graphics, and a map of each park. The atlas is available wherever books are sold.

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THE OPTIMIST'S GUIDE TO

EARTH DAY 2070

FIFTY YEARS AGO WE CELEBRATED THE FIRST EARTH DAY. WHERE WILL WE BE 50 YEARS FROM NOW? OUTLOOK: BRIGHT.

▽

Not feeling so optimistic? Flip the magazine for a pessimist's guide, including a look at the psychological toll of climate change.

—

ART BY ANDY GILMORE

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THE CASE FOR RENEWAL

We already have the tools to feed a larger population, provide energy for all, begin to reverse climate change, and prevent most extinctions.

BY EMMA MARRIS

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THE ROAD TO 2070

A 4,000-mile drive across the U.S. aims to find out if we truly can wean ourselves from fossil fuels.

BY CRAIG WELCH

PHOTOGRAPHS BY DAVID GUTTENFELDER

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FIGHTING FOR THEIR FUTURE

Ice sheets are melting and temperatures soaring as millions of young people come of age. They're tired of waiting for leaders to act.

BY LAURA PARKER

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FIFTY YEARS OF PROGRESS

In wealthy nations, the air, the water, and the land are cleaner than they were 50 years ago. The challenge: to make that true for everyone.

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PULLOUT POSTER

Where can preserving land and sea have the most conservation impact? We've mapped it.

ON THE COVER

An optimistic illustration of our thriving planet in 50 years.

IMAGINARY FORCES

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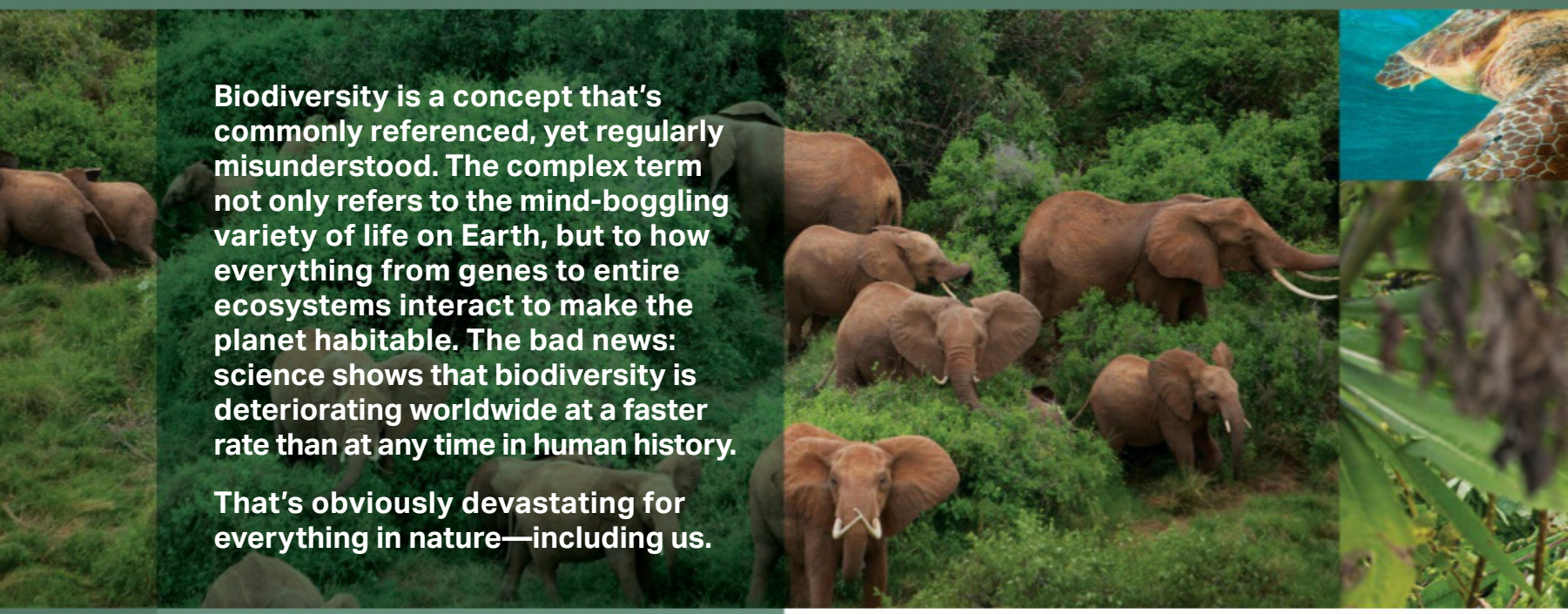
ADVERTORIAL FOR THE WYSS FOUNDATION

NATURE
NEEDS US TO ACT—NOW

Life as we know it depends upon biodiversity, which is why the **Campaign for Nature** seeks to protect at least 30 percent of the planet by 2030.



Biodiversity is a concept that's commonly referenced, yet regularly misunderstood. The complex term not only refers to the mind-boggling variety of life on Earth, but to how everything from genes to entire ecosystems interact to make the planet habitable. The bad news: science shows that biodiversity is deteriorating worldwide at a faster rate than at any time in human history.

That's obviously devastating for everything in nature—including us.

"If biodiversity disappears, so do people," says Dr. Stephen Woodley, field ecologist and biodiversity expert with the International Union for Conservation of Nature. "We are part of nature and we do not exist without it … ."

Every living thing—from microorganisms to behemoth blue whales—plays an integral role in supporting life on the planet. So, any nature loss has a negative impact. Suffer enough losses and the biosphere—the living layer of Earth that supports life as we know it—collapses.

Preventing such a catastrophe, says Woodley, begins with understanding why biodiversity is declining, and then taking action to reverse course.

"The two greatest causes of biodiversity loss are habitat loss, primarily on land, and overexploitation, primarily in the ocean," Woodley says. He explains that we can solve these problems by permanently protecting more lands and oceans and managing them for their conservation values.

That's the mission of the global Campaign for Nature, a partnership of the Wyss Foundation and the National Geographic Society. The foundation, created by entrepreneur, conservationist, and philanthropist Hansjörg Wyss, is committing one billion dollars over the next decade to help protect at least 30 percent of the planet by 2030.

Currently, only 15 percent of the land and 7 percent of the ocean are protected. The campaign calls on policy makers to invest in conservation and commit to The New Deal for Nature and People, a science-driven plan to save the diversity and abundance of life on Earth. This plan, which is currently being developed, is set to be finalized and signed in October at the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity in Kunming, China. The campaign is working to ensure that the plan establishes "30 by 30" as a global conservation target and is accompanied by long-term funding for management.

NATIONAL GEOGRAPHIC | WYSS CAMPAIGN FOR NATURE

Learn more at **campaignfornature.org/petition**

Instead of simply protecting 30 percent of the Earth, the campaign also encourages nations, in full partnership with indigenous peoples and local communities, to focus on the right 30 percent. Those areas, says Woodley, harbor the most important biodiversity values such as endangered species and ecosystems; rare species and ecosystems; examples of every living thing on Earth; unique aggregations like bird migration stopover points; and intact wilderness areas.

The campaign also recognizes the importance of indigenous-led conservation and of respecting indigenous rights. Indigenous peoples manage or hold tenure over lands that support about 80 percent of the world's biodiversity, making it essential for these communities to be full partners in developing and implementing strategies.

Protecting the health of key biodiversity areas also is vital for tackling climate change, says National Geographic Explorer-in-Residence Dr. Enric Sala, an author of a 2019 paper outlining the need for a Global Deal for Nature (GDN). Pairing the GDN and the international Paris Agreement to combat climate change, Sala's paper asserts, "would avoid catastrophic climate change, conserve species, and secure essential ecosystem services."

"Biodiversity is stability," says Sala. "Trees, wetlands, grasslands, peat bogs, salt marshes, healthy ocean ecosystems, mangroves, and plants absorb much of the carbon pollution humans put into the atmosphere. Yet, right now, less than half of the planet is in its natural state, which isn't enough … ."

Bottom line: Nature needs us to act—now.

"[Moving to] Mars is not an option," Sala adds. "The only conditions for our life and for the prosperity of human society are here on Earth … it is up to us to protect it."

This content was created for the Wyss Foundation. It does not necessarily reflect the views of National Geographic or its editorial staff.

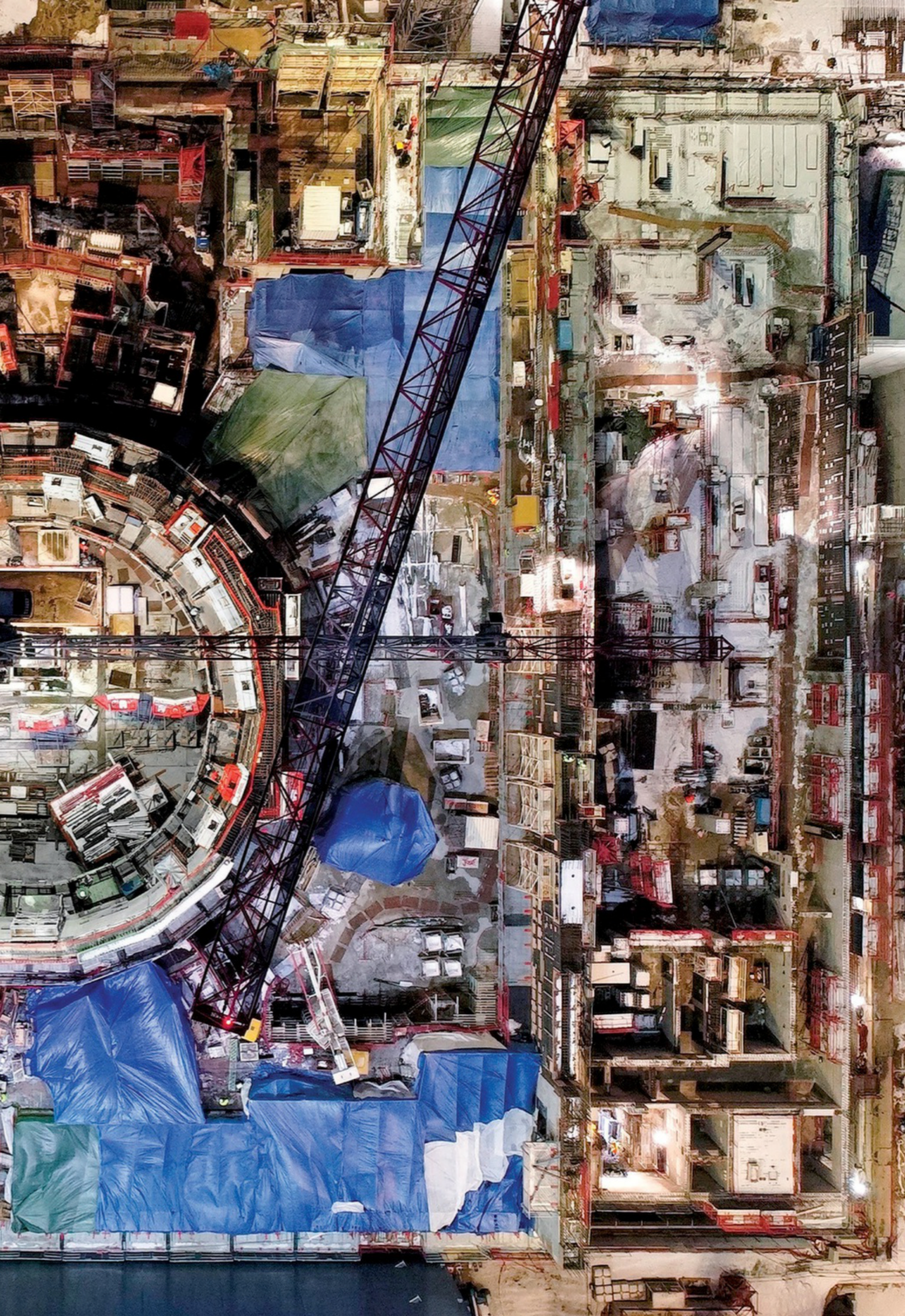
WE'VE GOT THIS

INGENUITY, COMPASSION, AND PERSISTENCE WILL HELP US COME UP WITH SOLUTIONS TO SOME OF THE PLANET'S BIGGEST PROBLEMS.

CONSERVATION WITH CARE

An orphaned elephant is comforted by a wildlife keeper at Kenya's Reteti Elephant Sanctuary, the first community-owned elephant sanctuary in Africa. Reteti has successfully integrated six orphans into wild herds.

AMI VITALE



NEW ENERGY

In southern France, 35 countries are building ITER, a thermonuclear experimental reactor, in an effort to harness nuclear fusion—the process that powers stars and potentially is an almost limitless source of carbon-free energy.

ITER ORGANIZATION/ EJF RICHIE

mares

ALTERNATIVE AGRICULTURE

A diver off Noli, Italy, harvests tomatoes from Nemo's Garden, an experimental underwater farm where plants grow without soil or pesticides—a possible boon for places without arable land.

ALEXIS ROSENFELD, GETTY IMAGES

LIVING WITH WATER

Decades of pollution control have made the water so clean in the industrial harbor of Aarhus, Denmark, that people now swim in seawater pools. A new floating complex makes it easy for residents to enjoy the waterfront.

RASMUS HJORTSHØJ

LIFE FINDS A WAY

Moss colonizes a discarded doll's head at Freshkills Park on Staten Island, New York. Once the world's largest garbage dump, the 2,200-acre space is being transformed into a recreation area nearly three times the size of Central Park.

LAURA WOOLEY

STEMMING THE TIDE OF WASTE IN A POLLUTED RIVER.

PROJECT BUTTERFLY is helping innovative solutions take flight to fight Africa's plastic waste challenge. In Nairobi, Kenya, the program funds and facilitates waste cleanup activities, education campaigns, and new ways to incentivize recycling. Just as a caterpillar transforms into a butterfly, the project is reshaping mind-sets, communities, and plastic waste in areas plagued by pollution and poverty.

PROJECT BUTTERFLY TACKLES WASTE THROUGH EDUCATION, COLLABORATION, AND HANDS-ON ACTION.

DON'T LET IT GO TO WASTE.

To learn more about these initiatives, go to DONT-WASTE.DOW.com

"Without waste infrastructure, trash is thrown into rivers, streets, beaches, or burned."

KEIRAN SMITH, CO-FOUNDER AND CEO OF MR. GREEN AFRICA

A stagnant river clogged with trash. Air choked with toxic fumes from burning waste. Development outpacing infrastructure. As Nairobi's burgeoning middle-class communities create explosive growth, the city's waste footprint is spiraling out of control.

Dow's Project Butterfly initiative in Africa unites residents, NGOs, government agencies, educators, community leaders, and manufacturers in unique partnerships to combat the crisis. By forging these crucial collaborations, the effort helps bridge the gap between recycling buyback centers, sorting facilitators, collectors, and recyclers. Often, it provides the first opportunity for residents to harvest waste and use it to generate wealth by collecting, sorting, and selling it to recycling organizations where it will be repurposed in a circular, renewable loop.

"The best way to change behavior is through education on the value of waste and the risks of mismanaging it."

CHEGE NGUGI, COUNTRY DIRECTOR, CHILDFUND KENYA

Despite Nairobi's daunting amount of unmanaged garbage, inroads are being made. Dow resources and technical assistance enable the waste-preneur organization Mr. Green Africa and child development NGO ChildFund to catalyze change. River cleanup events and recycling education sessions help residents understand the impact of uncontrolled waste, spotlight ways to reverse the trend, and build enthusiasm for a cleaner future. In communities where no trash pickup forces garbage into rivers, school programs are educating a new generation of sustainability-conscious citizens.

One person at a time, Project Butterfly is changing attitudes from "waste is something I want to get rid of" to "waste is something of value and there's a benefit to keeping it."

"Paying people for the plastic waste they collect means a steady income, access to health care, and a cleaner environment."

KEIRAN SMITH, CO-FOUNDER AND CEO OF MR. GREEN AFRICA

New transfer shops provide an organized, sustainable system to incentivize and empower waste pickers who comb streets and dumps for plastics. Collectors receive training to make sorting more effective, bring their daily supply to the shops, and receive payment based on weight. The plastic is then sent to recycling centers and processed into raw material to create new products and packaging. As a result, marginalized waste pickers are moving out of the shadows of society and gaining new dignity and respect for the waste management role they play.

Mr. Green Africa sees Nairobi and other emerging markets as a new frontier for positive waste management change. As communities embrace the idea that plastic is too valuable to lose, family livelihoods, security, and health improve while polluted environments transform.

"The Kenya we live in today is going to change. It will be clean because now we know better options for recycling."

MARY, MR. GREEN AFRICA EMPLOYEE

Project Butterfly proves the power of teamwork. For the first time, everyone from local school children and trash collectors to government officials and international development groups are collaborating, innovating, and accelerating solutions. Working together, a once-doomed river is changing course.

This content was created for Dow. It does not necessarily reflect the views of National Geographic or its editorial staff.

NATIONAL GEOGRAPHIC VOL. 237 NO. 4

THE CASE FOR RENEWAL

LIFE WILL BE DIFFERENT—AND WARMER—IN 2070. BUT WE WILL FIND WAYS TO LIMIT CARBON EMISSIONS, EMBRACE NATURE, AND THRIVE.

BY EMMA MARRIS

MY MOTHER'S BROWN HAIR is long and parted in the center. She is sewing a eucalyptus seedpod to a dress made of pale green drapery fabric, laughing with her friends. She is 19 years old.

It is February 1970, a few months before the first Earth Day, and students at San Jose State College in California are throwing a "Survival Faire," during which they plan to bury a brand-new yellow Ford Maverick. The Maverick and all combustion engines are to be declared dead because they belch pollutants that have helped create vile, ground-hugging smog in San Jose

HERE'S WHAT WE BELIEVE:

Most companies think having a strong opinion means scaring away customers who think differently. We think it's a good way to make some new friends. For the record, we believe we should eat stuff that we can grow instead of growing stuff to feed animals and then eat them. Everybody — regardless of spiritual beliefs, birth country, race, gender, sexual orientation or color of their nail polish – is of equal worth.

The reckless pursuit of profits without any consideration for the well-being of the planet and the humans that live here should be considered a crime. Companies have as much responsibility as politicians for building a society that the rest of the world can admire. Bigfoot the legendary Sasquatch is real. Okay, that last one has nothing to do with Oatly and is the personal belief of the guy writing this. Apologies, this ad is not a place for personal reflection.

and cities around the world. The Maverick, *San Francisco Chronicle* reporter Paul Avery wrote, "was pushed through downtown San Jose in a parade led by three ministers, the college band and a group of comely coeds wearing green shroudlike gowns."

My mother remembers those gowns well, 50 years later. The students that day were worried about dirty water and overpopulation as well as dirty air, but my mother was optimistic. "I assumed that human beings would step up when we had to," she says. And to an extent we did: Cars in the United States are 99 percent cleaner than they were back then, thanks to pollution laws.

Can you dig it?

In a February 1970 precursor to Earth Day, students at California's San Jose State College bought a new Ford Maverick, pushed it to the center of campus, and buried it 12 feet under. The ceremony was an anti-smog statement, part of a weeklong "Survival Faire" that gave rise to one of the first environmental studies departments at a U.S. university.

STAN CREIGHTON, *SAN FRANCISCO CHRONICLE*/POLARIS

I didn't inherit my mother's brown hair or her sewing ability. At 41, I still take my clothes to her for repair. But I got her optimism—and these days we have new things to step up about.

After 15 years of reporting on the environment for scientific and popular publications and for a book on the future of conservation, I am still frequently overwhelmed by the web of problems that face us: climate change, dwindling populations of wild plants and animals, widespread environmental injustice. They're all harder to fix than smog. But in the midst of a swirling sea of sorrow, anxiety, fury, and love for the beautiful weirdness of life on Earth, I find an iron determination to never, ever, give up.

What gives me hope? We already have the knowledge and technology we need to feed a larger population, provide energy for all, begin to reverse climate change, and prevent most extinctions. The public desire for action is bursting forth on the streets. Last September some six million people worldwide went on "climate strike." Just as in 1970, the electric crackle of cultural change is once again in the air. I believe we will build a good 2070.

It will not look like 2020 or 1970. We cannot undo what we've done; we cannot go back in time. Change—ecological, economic, social—is inevitable. Some of it will be tragic. We will lose things we love—species, places, relationships with the nonhuman world that have endured for millennia. Some change will be hard to predict. Ecosystems will reshuffle, species will evolve.

We will change too. Many of us will learn to see ourselves differently, as one species among many—a part of nature, not in opposition to it. I predict that we will look back at the late 20th and early 21st centuries as a painful, turbulent transition, during which humanity learned to thrive in positive ecological relationships with one another and with the species around us.

OUR BIGGEST SHARED CHALLENGE is climate change. If it seems overwhelming, it's in part because we, as individuals, can't stop it. Even if we're perfect green consumers—refusing to fly, reusing shopping bags, going vegan—we're trapped in a system that makes it impossible to stop adding to the problem. Living requires eating, getting to work, and staying warm enough in winter and cool enough in summer to work and sleep. For now, it's impossible to do these things in most places without emitting carbon.

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But change can happen faster than many people appreciate. Cars replaced horses within 15 years in many places. For thousands of years we got along without plastic, and then in a few decades it was everywhere. Throughout history, we've been both ingenious inventors and quick to adopt new technologies. With popular will and the right policies, we'll have no problem creating new energy and transportation infrastructures, goods made without toxins or carbon emissions, biodegradable plastic substitutes.

As individuals it's much more effective to spend our energy demanding those policies, which will make going green the cheaper, easier path, than it is to buy the expensive, niche-market green options available today. Increasingly I am seeing people realize this, and that too gives me hope. We cannot solve the climate crisis by being "good" consumers. But we absolutely can make things much better by being good citizens.

A quarter of emissions come from electricity and heat generation. Happily, with the political will, these are also the easiest emissions to eliminate. "We could easily cut it in half in 10 years," says Jonathan Foley, the executive director of Project Drawdown, which does cost-benefit analyses of climate change solutions. Wind and solar power are mature enough to deploy on a massive scale, and batteries to store the power—both centrally and house-to-house—are getting better and cheaper. Meanwhile, coal companies are going bankrupt.

WE CANNOT SOLVE THE CLIMATE CRISIS BY BEING 'GOOD' CONSUMERS. BUT WE CAN MAKE THINGS MUCH BETTER BY BEING GOOD CITIZENS.

Agriculture, forestry, and land use are trickier. They produce another quarter of our emissions—mostly nitrous oxide rising from manure or synthetic fertilizer, methane belched by livestock, and CO_2 from burning fuel and fields. By 2070 there may be more than 10 billion of us to feed. How do we shrink the land and climate footprints of farming and still produce enough calories to go around?

One solution is to stop subsidizing meat production and to encourage society-wide shifts to more plant foods. Beef in particular takes the most land and water; to grow a pound of it, you have to feed the animal about six pounds of plants. Luckily there's hope, in the form of tasty new meat alternatives such as the Impossible Burger or Beyond Meat. I don't imagine everyone will be vegan in 2070. But most people will simply eat far less meat than they do today—and probably won't miss it.

What about farms themselves? Environmentalists tend to fall into two camps. One camp says farming must intensify, using robots and GMOs and big data, so as to produce an astronomical amount of food on a tiny footprint. The other camp says farms must become more "natural," mixing crops and reducing toxic chemicals while leaving the borders of fields as wildlife habitat. After years of reporting on this, I wonder: Why can't we do both? We can have some urban "vertical farms" in skyscrapers running on renewable energy. We can also have large outdoor farms that are high yield and high-tech, friendly to wildlife and actively storing carbon in their soils.

The rest of our carbon emissions come from industry, transportation, and buildings. These are the ones that keep Foley up at night. How will we retrofit billions of buildings, replacing gas and oil furnaces? How will

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we wrestle some 1.5 billion gas-guzzlers off the roads? We can't count on hippie undergraduates to bury them all.

The only real option is for governments to drive the change with tax incentives and regulations. In Norway half of new cars registered are now electric, in large part because the government exempts them from sales tax, making them as cheap as gas-powered cars—the sale of which will be banned by 2025. In New York City the city council last spring adopted a law that will require large- and medium-size buildings to cut their carbon emissions by more than a quarter by 2030. Converting an entire country like the U.S. to efficient buildings, easy mass transit, and electric cars won't be cheap—but let's keep the expense in perspective. "The money we are talking about is not more than what we bailed out the banks with," Foley says, referring to the federal response to the 2008 financial crisis.

We know how to do this: That's the basic message of Project Drawdown. One of the most cost-effective solutions to climate change, Foley and his team say, is ensuring that girls and women have access to education and birth control. Women in Kenya, for example, went from having 8.1 children on average in the 1970s to just 3.7 children in 2015. When that decline was briefly interrupted in the 2000s, it was linked to an interruption of girls' access to education. Empowering women will help stabilize the global population—and limit demand for food and energy.

To tackle climate change, even as we turn global emissions down to near zero, we still will need to invest in methods to remove some greenhouse gases already in the atmosphere. Technologies to do this are promising but mostly in their infancy—except for trees, which in the short term at least are good at soaking up carbon. Trees have another advantage: They create forests, where lichen hangs and lizards doze, and monkeys holler back and forth while they gorge on wild figs. I've spent time in forests like that, and the dry word "biodiversity" can never convey their worth.

YOU MAY HAVE HEARD that we are in the sixth mass extinction. This assertion is based on the elevated rate of extinction, not the total losses so far. Fewer than 900 documented extinctions have happened since the 1500s, which is absolutely too many, and likely a substantial undercount. But given that scientists have assessed more than 100,000 species so far, it is hardly yet a "mass" extinction, which paleontologists define as a period in which at least three-quarters of all species go extinct. If we keep these rates up for a few million years—or massively increase them by crossing some threshold of climate or habitat destruction—then we could find ourselves in a mass extinction. But we are not there yet, and if we don't paralyze ourselves with despair, we can still change course.

New research suggests most species can be saved and wildlife restored to higher abundances with a combination of more parks and protected areas, restoration of some ecosystems, and a reduction in farmland. Agriculture currently uses a third of the Earth's land. But if we cut meat eating and food waste in half, increase crop yields, and trade food more efficiently, the researchers estimate, we could grow all the food we need on less land. That would create more space for other species.

Naturalist E.O. Wilson and others have called for a "half Earth" approach, in which half the planet is reserved as wilderness where human activity is carefully limited. Big parks are wonderful, and necessary for some species, but the effort risks displacing a lot of people. "For sure, they are necessary, and we probably need 20 percent or more," says Georgina

Breathing in, breathing out

Preserving tropical forests like this one, part of Arfak Mountains Nature Reserve in West Papua, Indonesia, is crucial to the well-being of the planet. As the trees in such forests grow—accounting for 60 percent of all photosynthesis on Earth—they take up many billions of tons of carbon dioxide each year, including some emitted by humans burning fossil fuels. But when the forests are logged or burned, they release the carbon. Safeguarding these immense carbon lockers is perhaps the most cost-effective solution to climate change.

TIM LAMAN

Mace, a biodiversity expert at University College London (UCL). "We also have to have people living with and alongside and amongst wildlife." In her vision of the future, people and other species share space nearly everywhere. "I'm a whole-Earth person, not a half-Earth person," Mace says.

I believe such hybrid thinking will be the norm in 2070. Borders will be softer, backyards messier. Wilderness corridors will thread through farmlands and cities; floodplains will store carbon, produce food, and control floods. Kids will climb trees in schoolyard orchards to pick fruit.

Safe places for kiwis

The flightless kiwi, indigenous to the island country of New Zealand, suffers from increasing drought and predation by stoats and dogs. Chicks are most vulnerable, so local conservation groups, such as Kiwis for Kiwi, collect eggs or hatchlings and rear them in safe havens until they can forage efficiently and protect themselves from predators.

JOEL SARTORE, NATIONAL GEOGRAPHIC PHOTO ARK

Wild places will still exist, and people will still fall in love with them. But they might look very different than they do today. As species move in response to climate change, trying to prevent ecosystems from changing will become impossible and, in some places, counterproductive. Instead we'll focus on making sure the planet retains most species with robust populations. The purist idea that all species can be sorted into "native" or "invasive" will be retired. It never made much sense anyway. Ecosystems are always in flux, and most have been influenced by humans for thousands of years.

Management won't be hands-off everywhere. In New Zealand and on other islands where non-native species are the main threat to beloved natives, we may use humane traps or genetic engineering to remove the newcomers. In other places, threatened species will need help adapting, maybe even a ride to new habitats that aren't too hot. Intensive management will be required for many species in the short term.

By 2070 huge swaths of the Earth will be managed by indigenous nations, as their sovereignty is finally taken seriously. That will benefit wildlife, since indigenous-run lands turn out to have more species on average than national parks. In some cases traditional methods honed over millennia may be revived—the ones that created the beautiful, thriving landscapes that colonizers encountered when they first invaded, and mistook for "wild" nature.

FOR MANY YEARS I focused on the science of extinctions and climate change, and I looked for technological and policy solutions like solar panels or more parks. Meanwhile, in my private life, I fought for justice for the poor and the oppressed. It took me way too long to connect those battles—to realize that forces such as colonialism and racism are part of the climate crisis and need to be addressed as part of the solution.

Those who benefit the most from fossil fuels aren't usually the people who suffer the most from their use. Power plants and their toxic fumes, for example, are disproportionately found in poor, nonwhite neighborhoods. The disconnect crosses borders: One analysis has suggested that the gap in per capita GDP between the poorest and richest countries is already 25 percent wider than it would be without climate change, largely because temperature increases in tropical countries reduce agricultural productivity. Larger storms, droughts, and floods are already hurting the world's poorest.

REAL APPRECIATION

ISN'T SPOKEN, IT'S POURED.

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The 2015 Paris Agreement included a mechanism for richer countries to help poorer ones, to begin to make things right. The funding so far is inadequate, but it can be expected to grow, especially once the U.S. government accepts the global scientific consensus and rejoins the agreement. Some funds could be used to build climate research centers in hard-hit regions—"a kind of epistemic reparations," according to Olúfémi Táíwò, a philosopher at Georgetown University in Washington, D.C. He points out that centuries of colonization concentrated not only wealth but also the best universities in rich nations, creating a brain drain out of poorer ones.

Real climate justice would make Earth more resilient even as it helped humanity heal from historic trauma and pain. In a sense, climate change is an opportunity for us to step up—to grow up—as a species.

IN A SENSE, CLIMATE CHANGE IS AN OPPORTUNITY FOR US TO STEP UP– TO GROW UP– AS A SPECIES.

THERE IS A NEW NEEDLEWOMAN in my family. My daughter, now 10, loves to sew. I like to imagine the life she'll lead when she is 60.

The first thing she notices as she wakes up in her city apartment in 2070 is the birdsong: a raucous dawn chorus, a multispecies symphonic alarm clock. It's easy to hear because there's no traffic noise. She flips on her light, powered by solar shingles that cover nearly every roof in the city. Her building is itself built of "drawdown blocks" made from carbon captured from the atmosphere.

She gets up, has some coffee. She doesn't have to hunt for "fair trade" or "bird friendly" coffee because everything on the grocery shelf qualifies. She hops on a zero-emissions train that automatically pauses for two minutes because cameras down the line detect a family of foxes approaching the tracks. The sky is bright blue, undimmed by smog, albeit a little hotter than in 1970. In the distance she can see elegant windmills spinning.

When she reaches her stop, she steps out into a huge cloud of migrating monarch butterflies, en route to milkweed patches growing in a nearby park. People on the platform pause and let the butterflies wash over them.

She gets a message: She's invited to a party to celebrate the 100th Earth Day—a party, not a protest. There are no reluctant politicians left to convince. There are no gasoline cars left to bury. There will be a band and dancing, six kinds of meatless tacos and *'ehpaa*—prickly pear cactus—imported from the Kumeyaay Nation, near San Diego.

As she walks down the street, she stops and picks a half dozen eucalyptus seedpods off the ground, remembering vaguely that there was some talk in the early 21st century about cutting them all down because they weren't native to the Americas. Holding them in her hand, she decides to sew them around the collar of her green dress to wear at the party.

She gets another message: It's me! I am 91 years old. I want to come to the party too. ▯

Emma Marris is the author of *Rambunctious Garden: Saving Nature in a Post-Wild World.* She is working on a book about wild animals and how we relate to them. For the magazine she has written features on urban rats and on Manú National Park in Peru.

WHEN YOU **DISCOVER WHAT'S**

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THE COMEBACK CREATURES

PHOTOGRAPHS BY JOEL SARTORE

IN THE 1980s the number of giant pandas in China hovered around 1,100. Now, after decades of focused conservation, giant pandas have been crossed off the endangered list. Habitat preservation, anti-poaching efforts, and advances in captive-breeding programs can offer a lifeline to the most endangered members of the biosphere. In 2019 a total of 10 creatures showed improved status on the list of threatened species produced by the International Union for Conservation of Nature. Many more need help, including these animals that conservationists are trying to pull back from the brink. —NINA STROCHLIC

SAVE TOGETHER

CRITICALLY ENDANGERED

Sumatran rhinoceros

Poaching and human encroachment have left fewer than 80 Sumatran rhinos in the world—a drop of more than 70 percent compared with 20 years ago. To stave off extinction, conservation groups, including the National Geographic Society, stepped in to relocate rhinos into sanctuaries and monitor the last wild rhinos in Indonesia. Births in captivity have brought hope that more breeding programs can save the species.

CRITICALLY ENDANGERED

Cotton-top tamarin

This tiny, long-haired monkey lives only in the tropical forests of Colombia, where agriculture and urban growth have led to a significant population drop in the past few decades. Proyecto Titi strives to reverse this: From 2011 to 2018, the organization, which is supported by the Disney Conservation Fund, protected nearly 14,000 acres of the monkey's habitat, launched education programs, and opened new reserves and field sites to build up the population. (The Walt Disney Company is majority owner of National Geographic Partners.)

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

A THREATENED PHENOMENON

Monarch migration

The monarch butterfly's annual trip south is one of nature's most spectacular winter events. Around 20 years ago the insects began to decline, possibly from climate change and forest loss. In 2014 Canada, Mexico, and the U.S. formed a task force to protect the butterfly's migration route. It may be working: In 2019 the monarchs' numbers grew, and they were found in 144 percent more forest area than in 2018.

TO STOP PLASTIC WASTE WE NEED A PLACE TO START

Without widespread infrastructure to manage waste, Indonesia is struggling with the effects of ocean plastics. Project STOP, one of several projects funded by The Alliance to End Plastic Waste, is working with local communities to create circular waste management systems that keep plastic waste out of the ocean, increase recycling and create jobs.

ALLIANCE TO END PLASTIC WASTE | STOP
WWW.STOPOCEANPLASTICS.COM

Learn more about this project at natgeo.com/alliance

WHAT YOU CAN DO FOR

IN THE HOME

Become an eco-friendly **pet owner:** Be careful how you use flea and tick products containing pesticides. Avoid cat litter made of materials obtained by strip-mining.

Minimize **food waste:** Use a digital meal planner to calculate ingredients and portions so virtually everything you buy and cook gets eaten. Learn how to store foods to prolong their usability.

Keep food scraps and waste out of landfills by **composting.**

Be sure to properly **insulate** your home and replace old, drafty windows with energy-efficient ones.

AT THE STORE

Green your **coffee** habit. Get a reusable filter pod for your single-use coffee machine—and fill it with certified "bird friendly" coffee grown in a habitat that also nurtures birds.

Be choosy when buying **home tissue.** Know which products are made of virgin wood pulp, which contribute to destruction of forests. Instead of buying paper towels and paper napkins, use cloth towels, napkins, and rags when possible.

Consider dropping **meat** from a few meals, or completely.

YOUR WORLD

INDIVIDUAL ACTS ALONE CAN'T FIX GLOBAL ILLS. BUT EACH OF US CAN DO OUR PART TO REDUCE ENVIRONMENTAL PROBLEMS AND PUT MORE ENERGY INTO THE SEARCH FOR SOLUTIONS.

● ILLUSTRATION BY TOMI UM

IN THE NEIGHBORHOOD

Help keep your community's vegetation healthy by organizing **tree-planting projects or pruning and weeding outings** to eliminate invasive plants.

Plant **pollinator gardens.**

With help from local water and conservation officials, arrange a **cleanup of a creek** or other waterway in your community.

AS A CITIZEN

Know the requirements for **testifying at hearings** or submitting written comment when federal agencies are seeking public input on an action or rule under consideration.

Check *townhallproject.com* to search by zip code for **town halls** and other events where you can speak in person to your local legislators.

Share your home-composting experience: **Hold workshops** in the neighborhood to encourage and teach others.

SOURCE: NATURAL RESOURCES DEFENSE COUNCIL (*NRDC.ORG*)

DISPATCHES
FROM THE FRONT LINES
OF SCIENCE
AND TECHNOLOGY

Move over, Edison

Light-emitting diodes, or LEDs, are the bulbs of the future (and the present). They can burn 25 times longer than incandescent lighting yet use up to 80 percent less electricity. By 2035, LEDs are expected to cut U.S. energy consumption from lighting by more than three-fourths. –DANIEL STONE

CLEAN ENERGY

HOW TO HARNESS WAVE POWER

A SWEDISH COMPANY HAS CREATED A DEVICE THAT CAN DRAW CHEAP, CLEAN ENERGY FROM THE CHURNING OF OCEAN WAVES.

THE APPARATUS ABOVE derives energy from the rise and fall of ocean waves and converts it into electricity. The technology, from the Swedish company Eco Wave Power, utilizes a sophisticated system of floats and hydraulic pistons. When a wave passes through the machine, the floats on the device move up and down, compressing and decompressing the pistons. The pressure from the pumping pistons powers a hydraulic motor; its mechanical energy is harnessed by a generator and turned into electricity. Because the apparatus is designed to be attached to coastal structures such as breakwaters, it has a much lower start-up cost than similar devices used offshore. –ANNIE ROTH

CLEAN WATER

MAKING PAINT WITH POLLUTANTS

In Appalachian Ohio many streams have been polluted with iron and other minerals in runoff draining from abandoned coal mines. Ridding the waterways of metals is expensive, but two Ohio University professors have found a way to help the process pay for itself. Guy Riefler, an environmental engineer, extracts iron from the polluted water. When the resulting material is fired at different temperatures by art professor John Sabraw, it changes color—and can be used in pigments (below) that Sabraw and other artists employ in their work. –AR

PHOTOS (FROM TOP): MARK THIESSEN, NGM STAFF (COMPOSITE OF TWO IMAGES); ECO WAVE POWER; REBECCA HALE, NGM STAFF

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NEW CHALLENGES FOR US ALL

THE SCARY PREDICTIONS OF 1970 INSPIRED ACTIONS THAT MADE LIFE BETTER IN MANY WAYS. NOW WE'RE BEING TESTED AGAIN.

BY CHARLES C. MANN

LET ME DATE MYSELF right away by saying that I attended a demonstration on the first Earth Day, in 1970. The mood, as I recall it, was both joyous and solemn. Joyous because we were collectively celebrating, for the first time in U.S. history, the natural world around us. Solemn because the voices from the podium were issuing dire prophecies about the fate awaiting that natural world.

Such warnings were heard everywhere then. The Nobel Prize–winning biochemist George Wald explained to an audience at the University of Rhode Island that unless immediate action was taken, civilization would end within 15 or 30 years. According to Stanford biologist Paul Ehrlich, author of *The Population Bomb,* that kind of prediction was overly hopeful. In an interview published for Earth Day, Ehrlich proposed that the planet had only two years left to change course before all "further efforts [to save it] will be futile." Too optimistic still, believed Earth Day national coordinator Denis Hayes. In an

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Earth Day–timed article for the Wilderness Society magazine, Hayes argued that it was "already too late to avoid mass starvation."

It's easy to understand why they believed this: The global situation *was* calamitous. At the time of the first Earth Day, about one out of every four people in the world was hungry—"undernourished," to use the term preferred by the United Nations. About half the world was living in extreme poverty. The average life expectancy in Africa was a mere 45.6 years. Roughly half of Latin America and the Caribbean lacked electricity and access to education. Famines in West Africa had just killed about a million people. Wars, revolts, and insurgencies were raging in Southeast Asia (Vietnam, Laos, Cambodia, Indonesia, the Philippines), Africa (Kenya, Ethiopia, Nigeria, the Portuguese colonies), the Middle East (Oman, Yemen, Jordan), and Latin America (Nicaragua, Colombia, Mexico). A flu pandemic that began in Asia was exploding through much of the rest of the world; it would kill a million people before it was over.

THE WORLD TURNED OUT QUITE DIFFERENTLY FROM THE DIRE FORECASTS OF 1970, WHICH FORESAW A RUINOUS DECLINE FOR HUMANKIND AFTER THE PLANET HAD BEEN STRIPPED OF ITS RESOURCES.

Environmental trends were, if anything, worse. Harbors from London to Los Angeles, Boston to Bombay (now Mumbai), were choked with waste. Most of the planet's great rivers—the Danube, the Tiber, the Mississippi—were undrinkable. Leaded gasoline released poisonous fumes into the air in such vast quantities that the average U.S. preschooler had four times more lead in his or her blood than what would now require urgent action. So much smog enveloped cities that *Life* magazine predicted early in 1970 that "by 1985 air pollution will have reduced the amount of sunlight reaching Earth by one-half."

By the first Earth Day, a recently founded international organization, the Club of Rome, was already working on what would become a stunningly influential book: *The Limits to Growth,* published in 1972. The *Limits* team created a computer model of the world, then used it to project future demand for resources such as coal, iron, natural gas, and aluminum. In graph after graph, the book depicts a race to a peak of production, followed by a ruinous decline as the planet is stripped bare. To avoid ruin, the team emphasized, humankind's lurching course forward "must stop *soon*."

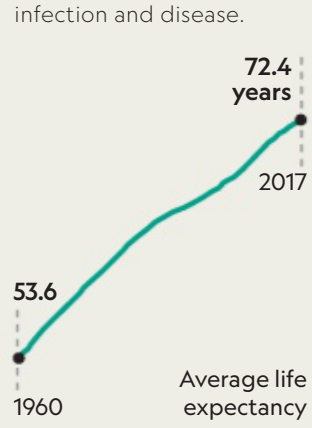
GLOBAL GAINS

People have more food to eat

Food production has outpaced population growth thanks to the expanded use of nitrogen fertilizers, increased irrigation, and higher-yielding seed varieties.

We're living longer

Improvements in sanitation, nutrition, and health have steadily lengthened life expectancy all over the world. Vaccines and antibiotics have reduced deaths from infection and disease.



Fewer women are dying in childbirth

Maternal deaths are much rarer today, including in some regions of Asia that have seen a 60 percent drop since 2000. Globally, improvements can be attributed to better health care, hygiene, and nutrition.

DIANA MARQUES, NGM STAFF; KELSEY NOWAKOWSKI. SOURCES: HUMAN PROGRESS, CATO INSTITUTE; FAO; WORLD BANK; UN STATISTICS DIVISION

UNBEATABLE STRENGTH* THAT'S EASY TO SWALLOW

WHAT PAIN?

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That didn't happen. The world turned out differently from the predictions—and, in many ways, better. Thanks to technological advances, political and economic reforms, and cultural changes, average human physical well-being has, by almost every measure, improved since 1970. Nowadays, according to the UN, just one out of nine people worldwide is undernourished, even though our numbers have more than doubled in the past 50 years. The chance that a child will be hungry in our era is lower than it has been in recorded history, and as relief efforts have improved, famine deaths, once common, have become increasingly rare. (Hundreds of millions of people are still underfed, but it's important to recognize what has been accomplished.) Partly because of better health and nutrition, average global life expectancy has risen by more than 13 years since the first Earth Day, with most of the increase occurring in low-income places. All the while, incomes have been rising and pollution levels falling—almost, but not quite, everywhere. Billions of people now belong to something that resembles the middle class.

Meanwhile, resources such as steel and aluminum are far from running out, and generally cost the same or less. In the history of our species, nothing like this gush of good fortune has occurred before. It is the signal accomplishment of the postwar generation and its predecessor.

Even the political situation has improved, despite the polarization besetting North America and Europe today. Every research project tracking global political violence shows that it has been falling precipitously; the civil wars in the headlines—Syria, Yemen, and Afghanistan—are ghastly but exceptional. There are many more democracies and partial democracies now than in 1970, and they are working, however unsteadily, to improve their citizens' lives. At the time of the first Earth Day, fewer than one in five people in South Asia had electricity; today the figure is more than nine out of 10. Similarly, the proportion of people in Latin America and the Caribbean with electrical power has risen from less than 50 percent to almost 100 percent.

These improvements have not occurred evenly or equitably: Millions upon millions are not prosperous, and millions more are falling behind. Some places, notably in India and China, are becoming more polluted, not less. But on a global level—the level of the nearly eight billion souls currently inhabiting our planet—the increase in well-being is indisputable. The factory worker in Pennsylvania and the farmer in Pakistan may be struggling and angry, yet they are also, by the standards of the past, wealthy and healthy.

The gains have been accompanied by losses, though. The list of environmental problems is different than it was in 1970, but it also may be more formidable. Biodiversity loss, aquifer drainage, ocean acidification, soil degradation, and, biggest of all, climate change—who can look at this list without quailing?

One lesson of the failed predictions of the first Earth Day is that people can solve environmental problems—if, like air and water pollution, they have immediate, tangible effects on humans' physical welfare. But the problems we face today are much more long-term and abstract, if no less serious. They are not, for the most part, like what we have faced before. Nobody knows whether they can be cracked. And another lesson of those failed predictions is that humans are terrible at foreseeing the future. ▯

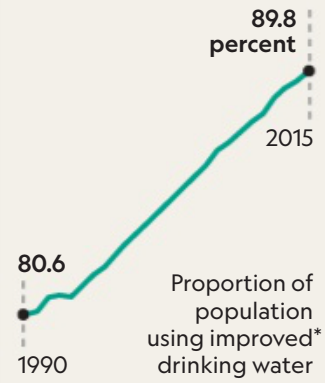
Charles C. Mann is the author of *1491, 1493,* and *The Wizard and the Prophet*. He's also a correspondent for the *Atlantic, Wired,* and *Science*.

We're spending more time in the classroom

Wide gains in education came from greater public and private investment, as well as an increased appreciation of its benefits. In many regions the gender gap in learning has been nearly eradicated.

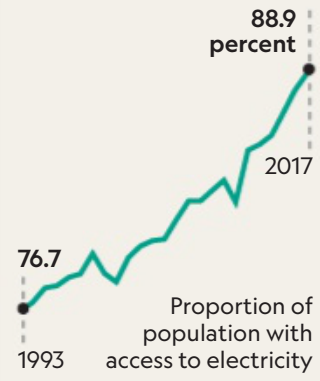
We have better access to clean water

Investments in piped water, public taps, and wells have increased urban and rural access to clean drinking water. Better sanitation also helps fight life-threatening fecal contamination of water.



More people have electricity

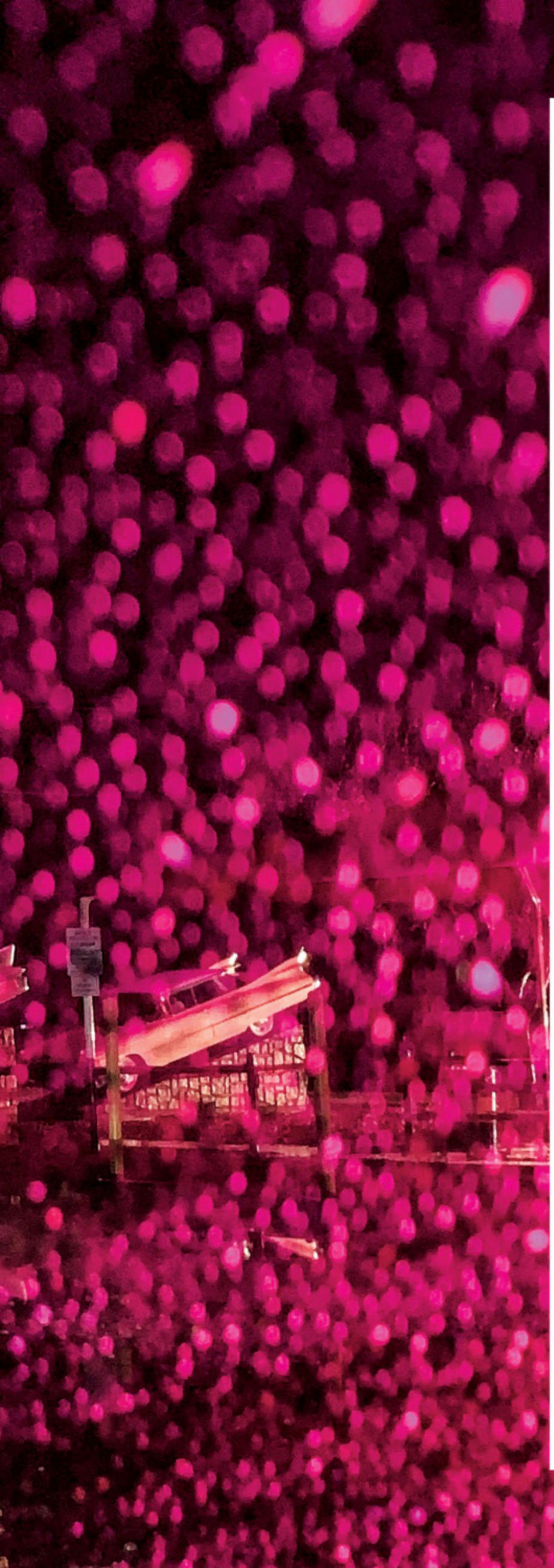
The share of the world's population with access to electricity has grown as more people have settled in cities. Off-grid technologies such as solar energy help wire poor, hard-to-reach rural areas.



SOURCES: BARRO-LEE EDUCATIONAL ATTAINMENT DATASET; UN STATISTICS DIVISION; WORLD BANK

*Water sources protected from outside contamination

Tail fins point into the rain at the Cadillac Ranch RV Park in Amarillo, Texas. For a century the automobile has been an American totem. But with well over a billion vehicles worldwide now fueling climate change, the internal combustion engine faces a reckoning.



EARTH DAY 2070

THE ROAD TO 2070

- BY CRAIG WELCH
- PHOTOGRAPHS BY DAVID GUTTENFELDER

A CROSS-COUNTRY TRIP IN ELECTRIC CARS REVEALS HOW NEW IDEAS COULD HELP POWER OUR JOURNEY TO A SUSTAINABLE FUTURE.

Wind turbines and solar modules blanket the Mojave Desert in Kern County, California, one of the country's densest concentrations of renewable energy. The solar and wind industries have grown rapidly and now power millions of homes. Yet they still produce less than 10 percent of all electricity in the United States.

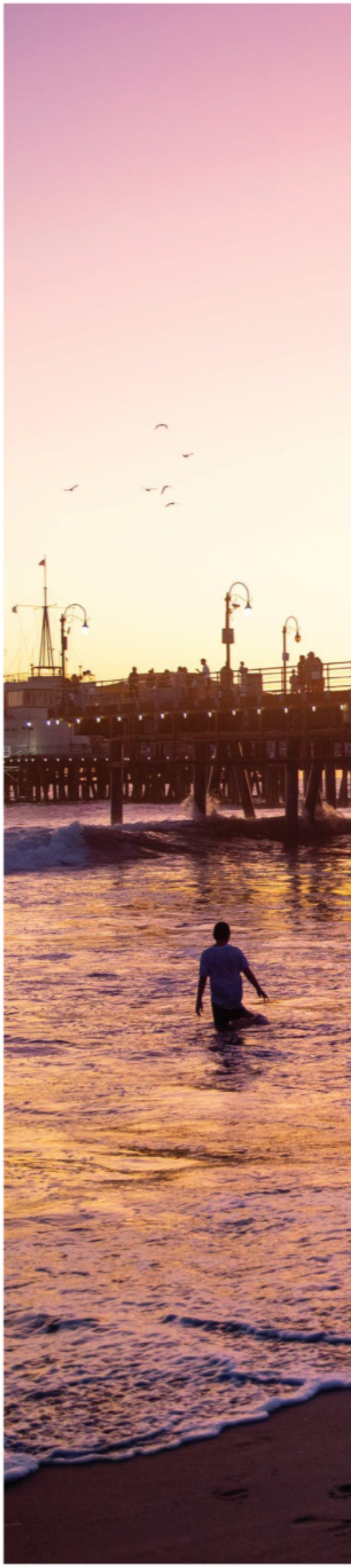
The furnaces at SSAB America's steel mill in Montpelier, Iowa, are electric—and by 2022, the company says, they'll be heated by renewable energy. The iron and steel industry, which usually relies on coal, accounts for about 7 percent of global CO_2 emissions. Heavy industry is especially hard to wean off the cheap heat that fossil fuels provide.

ON A WEATHERED PROMENADE

at the edge of the Pacific, near the photo booths and the pretzel stand and a man molding busts of tourists out of clay, spins a Ferris wheel that draws electricity from the sun. A few hundred feet away, a sign marks the end of old Route 66. The Santa Monica Pier, where green energy meets automotive history, seemed like the perfect spot to kick off a cross-country road trip in electric cars.

Route 66, one of America's first all-weather highways, began in Chicago. From the 1930s until it was rendered obsolete by interstates, it funneled millions of Midwestern migrants past motor lodges and trinket shops toward the sparkling shores of California. It helped reshape that state from a rural paradise to a series of sprawling cities. Along the way it came to symbolize so much: the transformational power of cars, the freedom of the open road, the magic of combining the two in a road trip. Today Americana-hungry travelers, after rolling through more than 2,200 miles of old 66, line up at a wooden hut on the Santa Monica Pier for signed certificates.

The pier is also a good place to reflect on the world we've created, in part through our love affair with the internal combustion engine. To the east lies Los Angeles with its seven million gas-guzzlers, which emit more carbon dioxide than a dozen states. To the south there's Venice Beach, which in the 1940s was crowded with oil derricks—and where in recent years starving sea lions washed ashore, victims of ocean heat waves worsened by climate change. To the west and north lie Malibu and the hills above it, where the Woolsey fire



The Santa Monica Pier is linked to Chicago by old Route 66—and by its solar-powered Ferris wheel. The 1893 Chicago world's fair showcased the first Ferris wheel, along with a new form of energy: electricity. To millions of Americans, the future looked exciting.

raged in November 2018, after years of drought and rising temperatures. The blaze killed three people, forced a quarter million to evacuate, and destroyed 1,075 homes.

The Santa Ana winds "blew that fire incredibly fast, right down to the coast in a day," Dean Kubani recalled on a hot day last fall, as we stood beneath the Ferris wheel. Kubani had recently retired as Santa Monica's sustainability chief, after 25 years with the city; he had watched the Woolsey fire from the beach. "Normally fire season is September, October," he said. But it lasts longer now "because we're not getting the rain, and we're not getting the cool weather."

For anyone wondering what living in California, America, or the world will be like in 2070, this is a critical moment—and a confusing one. The United Nations Intergovernmental Panel on Climate Change says we must slash greenhouse gases to zero over the next half century, if not sooner, to forestall a climate disaster. Instead the world is producing more fossil fuel, not less. Oil and gas companies in the United States, already the top producer, plan to boost development 30 percent by 2030. President Donald Trump has moved to take the

country out of the Paris climate accord, which aims to start weaning the world off fossil fuels.

Yet we also are undergoing a green energy revolution. Globally, renewable energy in the next five years is on track to increase by an amount equal to the electric power capacity of the United States. The fastest growing U.S. occupation in the next decade, according to the Bureau of Labor Statistics? Solar panel installer. (Number two: wind turbine service technician.)

Across the nation, cities and states are pledging to change. This year California began requiring solar panels on new homes. The city

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Oatman, Arizona (left), once a mining town where burros brought gold and silver out of the hills, later was a way station for migrants on Route 66. Today it's a tourist attraction, with wild burros dozing in the shade and Wild West "gunfighters" performing shows daily. Elsewhere in Mohave County, a solar-powered data center is under construction.

The table in this Tucumcari, New Mexico, restaurant is real; the dining couple is a trompe l'oeil mural. The painting above shows a scene, once common in the West, of cattle gathering around water pumped by a windmill. Future landscapes will have to contain many more wind turbines and solar farms, particularly if we turn away from nuclear power.

of Berkeley has banned natural gas in new buildings; Santa Monica and others are taking similar steps. Los Angeles wants to install 28,000 electric-vehicle charging stations in just eight years; Santa Monica is looking at 300 by 2021.

"When I first started here, the city had one electric car, and it was a converted Ford Taurus, I think, a station wagon," Kubani said. It had solar panels on the roof. "You could drive it about 10 miles." Photographer David Guttenfelder and I were planning to drive more than 4,000 miles in a series of electric cars. Loaded with bananas (for me) and beef jerky (for Guttenfelder), we left Santa Monica, bound for the East Coast, with one pressing question: Can we as a nation get where we need to go—meaning, can we get off fossil fuels fast enough to keep 2070 livable?

NORTH OF LOS ANGELES, in Kern County, petroleum is still pumped from large oil fields. But to the east, beyond the dusty Tehachapi Mountains from Bakersfield, the local oil capital, a cleaner future shimmers in the heat. We rolled into the desert town of Mojave in our rented Hyundai Kona and parked in a clothing store lot, where gusts of wind whipped the dresses around headless outdoor mannequins. Across rusty train tracks, we could see wind turbines towering over fields of solar panels, in what may be the country's densest concentration of renewable energy.

Ben New, vice president of construction for 8minute Solar Energy (named for the amount of time it takes sunlight to reach the Earth), led us to a 500-acre cluster of solar modules that produce 60 megawatts of power, enough for 25,000 California homes. Wiry and silver-bearded, New spoke hurriedly, like someone used to racing the clock. "Twenty years ago, a solar panel was so expensive that nobody would have ever thought you could ever do anything like this," he said.

Today solar is a steal. The price of photovoltaic modules has plummeted 99 percent since the 1970s, thanks in large part to public policy and research—in Germany, Japan, China, and the United States. As governments pushed utilities to boost renewables, demand skyrocketed. Production got more efficient. Prices fell. Installing a watt of solar costs New a fifth of what it did 10 years ago and takes half as much space.

It took four decades, until 2016, for the U.S. to install a million solar-power systems, from home rooftops to utility-scale solar farms. It took only three years, until 2019, to install the second million. By 2023, the number is projected to double again. The U.S. now has enough solar power for 13 million homes. Projects are getting larger: New's company has announced a deal for another 400 megawatts, with battery storage for 300. These and other 8minute projects will provide clean energy to one million Angelenos.

Impressive as these numbers are, however, they're nowhere near enough. Today less than 2 percent of U.S. electricity comes from the sun, and another 7 percent or so from wind. The global numbers are comparable. To cap warming at 2.7 degrees Fahrenheit (1.5 degrees Celsius), a recent UN report estimated, global emissions must fall 7.6 percent annually for the next decade. Last year they rose again. Getting renewables to fill the gap, the report said, would require them to grow six times faster than they've been growing.

That would mean massive mobilization and infrastructure investments—in steel and cable manufacturing capacity, in batteries and electric transmission lines. In the U.S., where the grid is split in three—one each for the East, the West, and Texas—it would require a major overhaul to ship power from sunny Arizona to coal-rich West Virginia. For now, New said, we'd have to produce many gigawatts "in areas of the country that have never done it before." That would entail permitting challenges in places where fossil fuels are popular. Eager as New is for a swift transition to solar, he doesn't see it happening in time. A 30 percent tax credit for solar investment, in effect since the George W. Bush administration, is to begin phasing out this year.

Could solar spread at the needed pace with the right encouragement? Experts have misjudged its potential before. In 2008 Harvard professor David Keith predicted we'd be lucky to see 30-cents-a-watt solar by 2030. It will hit that price in 2020. "We were totally wrong," Keith said recently. "Cheap solar is real. It is stunning."

As we said goodbye to New, I thought about how quickly technological change can come to America, from the rise of smartphones and social media to the spread, in just the past few years, of plant-based meat substitutes to burger joints across this beef-eating land. Later that evening, Guttenfelder and I pulled into the Mojave Air and Space Port, a testing and launch facility not far from where Chuck Yeager first broke the sound barrier in 1947.

The spaceport attracted us because it had installed electric-vehicle charging stations. We

plugged in our Kona, and a message appeared on the dash: Charging would take nearly six hours. Leaving the car for the night, we hiked, foreheads tucked in against the gritty breeze, almost a mile to the nearest motel.

THE AMERICAN ROAD TRIP began with a bet. In 1903, before interstates and filling stations, a patron in a California private club wagered $50 that Horatio Jackson, a physician, couldn't drive an automobile to the East Coast. Four days later, according to *Horatio's Drive: America's First Road Trip,* a 2003 film and book by Dayton Duncan and Ken Burns, Jackson and a mechanic bounced out of San Francisco in a 20-horsepower Winton touring carriage. They adopted a bulldog named Bud and fitted him with goggles to protect his eyes from dust. They roared up mountain passes on unpaved tracks, splashed through streams, broke down and got towed by horses, and waited for spare parts to arrive by train. Jackson hit New York 63 days later, completing the nation's first cross-country car journey.

The road trip is now woven into the American psyche—as a vehicle for discovery; as a chance to remember, forget, move on, or get lost. Guttenfelder and I, both Midwesterners—he's from Iowa, I'm from Kansas—had taken our own cross-country journeys as young men. Mine introduced me, at 21, to the craggy landscapes of the West: the Tetons, the Olympics, the Sierras, the Grand Canyon. It changed my life. Less than a year later I moved to Wyoming. I've lived less than an hour's drive from mountains ever since.

For now, cross-country travel by electric car requires retooling expectations. Fully charging can take an hour—or up to 24, depending on the battery and the charger. With the exception of Tesla's more than 750 proprietary supercharging locations, there are few places in the U.S. to juice up quickly, whereas there are close to 150,000 gas stations. But most electric vehicles can charge at night, at home. And Tesla, with the country's most robust fast-charging network, also has around 3,800 slower charging stations.

After Mojave, we blew past salt flats and glided into the narrow Panamint Valley. Under ideal conditions, our Kona could travel about 260 miles on a charge. But we were chugging up mountain passes and cranking the air-conditioning against hot winds that rattled the doors. I'd read that each could undercut battery life, which sparked our first of several bouts of "range anxiety." It ended uneventfully in Death Valley, where we found a lavish lodge with a charger.

The next day we topped off in the lot at the World's Tallest Thermometer, a towering pillar commemorating the global temperature record: 134 degrees Fahrenheit, set in 1913. Killing time in the gift shop among the T-shirts and ball caps, I thought back to the hut on the Santa Monica Pier where road trippers got their Route 66 memorabilia. Ian Bowen, the manager, told me he had grown up "the bored kid in the back seat," as his family blitzed across Nebraska and Iowa on vacations, whizzing past roadside temptations.

CAN SOLAR POWER SPREAD FAST ENOUGH? EXPERTS HAVE UNDERESTIMATED ITS POTENTIAL BEFORE, AND TECHNOLOGY CAN BRING RAPID CHANGE.

"I never understood as a kid why we would drive if we weren't going to take our time," Bowen said. To him, road trips are for slowing down and exploring. For now, extended stints at charging stations "really fit into that."

Pushing cars and trucks onto the grid is a central part of the strategy for getting America and the world off fossil fuels. In the coming decades it will dramatically increase demand for electricity. Once, the market would have responded with more coal-fired power plants, but no more. The new 8minute project, for example, will deliver energy to Los Angeles for less than two cents a kilowatt-hour—much cheaper than coal.

WE CAME UPON RUSSELL BENALLY one evening as he was checking on his horse on a rocky overlook

In 2019, 40 years after the partial meltdown of a reactor at Pennsylvania's Three Mile Island Nuclear Generating Station—America's worst commercial nuclear accident—the plant closed for good. Nuclear plants are expensive to build and run but generate carbon-free electricity around the clock. They provide nearly 20 percent of the country's electric power.

outside LeChee, Arizona, a small Navajo community near Lake Powell. In the distance, silhouetted by a dying sun, was the Navajo Generating Station. With its trio of columnar stacks, the largest coal plant west of the Mississippi resembled a beached riverboat.

This 45-year-old plant, which had produced enough electricity annually to supply two million homes—Los Angeles got some of its power from here until 2016—was shutting down because it could no longer compete with cheap gas and renewables. The closure would eliminate hundreds of jobs, almost all held by Native Americans. And while the Navajo and Hopi tribes didn't own the plant, they received millions in royalties and lease payments, money that will be hard to replace. But the plant had been a big polluter, generating 14 million metric tons or more of CO_2 a year. Galling to some in the Navajo Nation: That bad air came from energy that mostly went elsewhere. "A lot of people here still don't even have electricity," said Benally, a retired Navajo plumber.

We followed him home to meet his wife, Sharon Yazzie. She grew up in LeChee and remembers life without the station. She said

18+

WHAT IS AVAXHOME?

AVAXHOME-

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she won't miss it at all. "It's always provided for the outside rather than for ourselves," she said.

The coal plant closure is part of a trend that seems unstoppable. More than 500 U.S. coal-fired plants have closed since 2010, and dozens more closures are expected. U.S. coal consumption in 2019 was the lowest it has been in 40 years; in April, renewables generated more electricity than coal for the first time. China and India are still adding coal plants, but there are hints of a shift there too. Many Chinese plants now run only sporadically; India in 2018 added more renewable energy than coal.

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A pump jack (left) bobs in a cotton field near Lubbock, Texas, at the northern edge of the Permian Basin. Fracking of deep shales allowed this region to pump more than one-third of U.S. crude in 2019. For the month of September, when this photo was taken, the U.S. was a net oil exporter for the first time since monthly recordkeeping began in 1973.

A web of steel rebar forms the base of one of 120 future turbines at Sage Draw wind farm in the Permian Basin. Texas generates more energy from wind than any other state, helping drive down the cost. Wind power is so cheap that ExxonMobil has contracted to buy most of this 338-megawatt farm's output—in order to power more fracking for oil and gas.

RECHARGING THE ROAD TRIP

A reporter and a photographer for *National Geographic* drove across the contiguous United States in a series of electric cars to explore our energy future—and the future of the American road trip. They made the journey with no gasoline, myriad adventures, and fresh answers to an urgent question: How close are we to ditching fossil fuels?

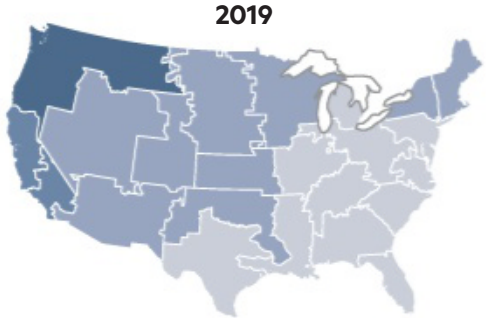
CONVERSION TO CLEANER ENERGY

The U.S. government projects that the renewable contribution to U.S. electricity will rise from 19 percent to 38 percent by 2050—a big increase, but nowhere near enough to meet climate targets. The West leads other regions thanks in part to abundant hydropower. But future increases will be driven by expansion in wind and solar.

PORTION OF ELECTRICITY GENERATED BY RENEWABLE ENERGY SOURCES, BY EIA REGION*

20 40 60 80%

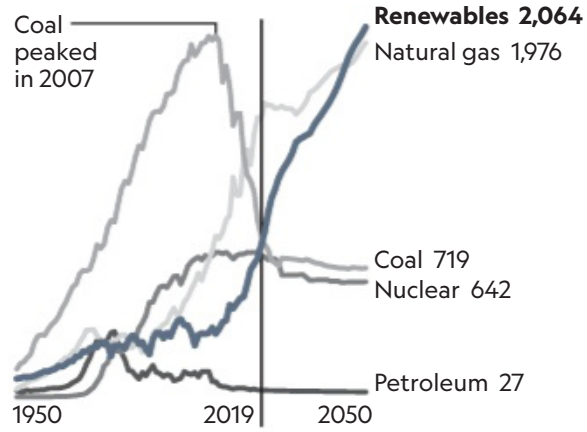
2019



RENEWABLES RACE AHEAD

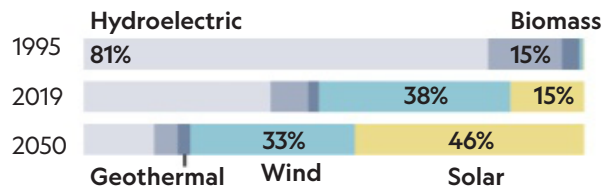
Renewable energy—predominantly wind and solar—is projected to eclipse all other sources of electricity by 2045, largely due to state mandates and falling costs.

U.S. ELECTRICITY GENERATION BY MAJOR ENERGY SOURCE, 1950–2050
in billions of kilowatt-hours



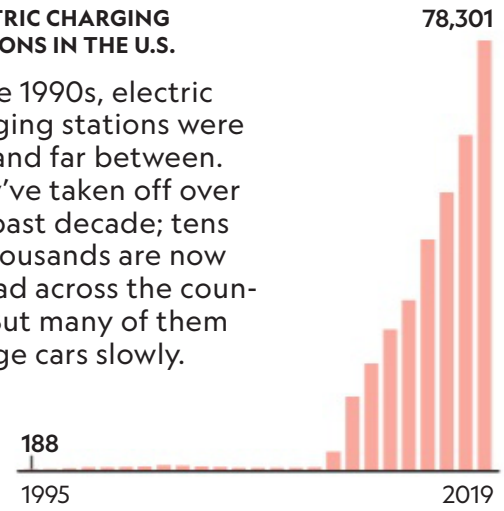
Wind energy currently makes up a larger part of renewables than solar, but not for long. Solar is projected to triple its share by 2050 to become the leading renewable.

SHARE OF RENEWABLE ENERGY, BY SOURCE



ELECTRIC CHARGING STATIONS IN THE U.S.

In the 1990s, electric charging stations were few and far between. They've taken off over the past decade; tens of thousands are now spread across the country. But many of them charge cars slowly.



RYAN MORRIS, NGM STAFF; SCOTT ELDER

*NO DATA FOR ALASKA AND HAWAII
SOURCES: VAISALA; U.S. ENERGY INFORMATION ADMINISTRATION (EIA); OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

A few miles from LeChee, in Page, Arizona, we parked our new rental, a white Tesla Model S, at Horseshoe Bend, a majestic meander in the Colorado River. Hundreds of visitors swarmed an overlook. The coal plant closure was a blow, Judy Franz, director of the Page Chamber of Commerce, told us, but tourism is up. More Navajo families were starting guide services and restaurants.

"There was a little bit of fear at first for a lot of people," Franz said. But "we'll be fine."

OVER THE NEXT SEVERAL DAYS we drove a giant S curve through the future and the past as they coexist in uneasy tension. Crossing into southern Utah, we glided past sparse forests and mounds of white stone. We worked through the remote terraced earth of Grand Staircase–Escalante National Monument, the last region in the lower 48 states to be mapped. After a lengthy stop at a slow charger in Boulder, Utah—population 240—we pushed toward Colorado.

At the National Renewable Energy Laboratory (NREL) outside Denver, a driverless electric minibus recently had begun shuttling scientists from the parking garage to their offices. Guttenfelder and I watched one of them, David Moore, in lab coat and gloves, slather liquid with a paintbrush onto a credit card–size conductive glass square, transforming it instantly into a tiny solar cell. The liquid contained dissolved perovskites, a kind of semiconducting crystal that is unusually efficient at harvesting sunlight. Some believe perovskites could prove as transformational as the iPhone, making solar power ubiquitous and dirt cheap.

"There is no reason that I can't deposit all of those materials on the side of a brick wall, on the side of a wood wall, on a south-facing wall … anything the sunlight hits," Moore said. "The top of a car. Wearable clothing. Wearable backpacks." He envisions solar cells printed on rolls of thin film, like newspapers on presses, making them easy to mass-produce quickly. Industry insiders are intrigued but skeptical. Breakthroughs often fail outside the lab.

Many will arrive between now and 2070—the bigger question is how fast the vested interests will let old technologies die. In Texas we confronted that dynamic.

One muddy morning southeast of Lubbock we watched a flatbed truck haul a wind turbine part across cotton farms. It, like us, had just crossed the Texas plains to reach Sage Draw, a 41,000-acre wind project under construction. We donned hard hats and stomped around an earthen pit where a latticework of rebar would soon brace a wind tower, one of 120 that together will generate 338 megawatts.

Texas, so synonymous with oil that the state flower could be a bobbing pump jack (it's actually the bluebonnet), now generates more wind energy than all but four countries. The legislature ordered utilities to spend billions upgrading the state's electric grid, stringing thousands of miles of new transmission lines so that wind projects in gusty West Texas could sell power to eastern cities such as Dallas. It worked spectacularly. By 2017, the Lone Star State was producing a quarter of the nation's wind electricity.

At the same time, though, the Permian Basin in West Texas and New Mexico was becoming one of the world's largest oil plays, thanks to advances in hydraulic fracturing, or fracking. Texas now produces more than twice what Alaska did at its peak, in 1988. Just the excess natural gas that companies burn or vent, for lack of pipelines to sell it, tops 800 million cubic feet a day, according to Rystad Energy—enough to cover consumption in the entire state of Washington, where I live. Flaring gas releases CO_2; the vented natural gas is mostly methane, which warms the planet even more powerfully.

At Sage Draw, the Texas wind and oil booms meet. ExxonMobil plans to increase its oil development in the Permian by 80 percent in four years. To help power its operations, it has agreed to buy most of the renewable electricity produced at Sage Draw and a nearby solar farm, both of which are owned by Denmark-based Ørsted. Frank Sullivan, head of strategy at Ørsted's American onshore business, called the agreement "a powerful indicator" of clean energy's new competitiveness. It's also an indicator of our strange moment. In Texas, clean energy is helping to extract more fossil fuels—when it needs to replace them altogether.

OF COURSE, MOST OF US STILL BUY what ExxonMobil sells. And crossing this divided nation makes clear that some Americans aren't eager for change. In Tucumcari, New Mexico, near the lovingly maintained Blue Swallow Motel, drivers can find a small EV charging hub at an old Conoco filling station. The day we arrived, someone had blocked it with a Ford F-250 pickup.

In Kansas a truck carrying a giant wind turbine

blade failed to negotiate a corner, blocking traffic. As vehicles backed up, a pickup peeled out and turned around, belching black smoke. The frustrated driver was "rolling coal." He'd modified his diesel engine to spew extra exhaust at the flip of a switch—an anti-environmentalist protest also known as Prius dusting.

Yet attitudes are changing; Americans embrace the energy transition when it works for them. Wandering through the amusement park glare of Las Vegas, with its illuminated fountains and floodlights sweeping the sky, I gawked at the energy profligacy. But a new law requires that half the state's electricity come from renewables by 2030. Next door in equally sunny Arizona, a utility spent $38 million in 2018 defeating a ballot initiative with similar aims. This year, though, it changed course, announcing a goal of going 100 percent renewable by 2050.

In Colorado we met software engineer Kevin Li as he charged his 2018 Tesla Model 3. He'd just picked it up in California and was driving home to North Carolina. When I asked what role climate change played in his going electric, Li looked confused. I repeated the question: Did he buy a Tesla out of a deep-seated concern for global warming?

"Nope," Li said.

Then why?

"Speed," Li said, smiling. "It's fast—really fast."

In western Kansas we spent a day in Greensburg, population 790. In 2007 a tornado wiped out more than 90 percent of this farm town, killing 11. When it came to rebuilding, some suggested Greensburg become sustainable—a "green burg." That sounded rather hippie to Bob Dixson. "All I could think about was 1968, powder blue bell-bottom pants, tie-dyed shirt, big white belt buckle, hair down to here, maybe on mind-altering chemicals, hugging a tree," the onetime mayor has said.

But, Dixson told me, he came to see it as a return to the virtues of his prairie-settling ancestors. Kansas pioneers built windmills to power wells, lived in sod houses—early green-roofed buildings—and stored food in root cellars. Greensburg's new school uses solar and geothermal heating, and the rebuilt community generates electricity from wind. Greensburg's grid is now 100 percent carbon free.

ONE NIGHT IN DES MOINES, Iowa, as I settled into a hotel room, Guttenfelder texted from across the hall. An unexpected visitor would be speaking two hours away the next day: Swedish teenage climate activist Greta Thunberg. She was crossing the country in a Tesla too, but in the other direction.

We pulled into Iowa City as thousands were gathering. I saw a hand-drawn picture of the planet captioned "Help Me I'm Dying." Thunberg joined local students on stage. "Right now the world leaders keep acting like children, and somebody needs to be the adult in the room," she said. The crowd roared.

Thunberg had sailed to the U.S. instead of taking a plane; one flight can produce more CO_2 than some people produce in a year. With climate stakes rising and air travel increasingly popular, some Europeans and Americans, including scientists, have curtailed jet travel. Guttenfelder and I talked about how deeply fossil fuels permeate our lives.

Earlier in our trip, I'd even flown home for my daughter's 11th birthday. I felt guilt at contributing to a slightly less livable world for her. I felt frustration at being forced to choose between her present and future. But the goal has to be to build a world where people can travel without carbon guilt. At NREL, teams are researching jet fuels made from algae or food waste. In December the first electric commercial airplane, a six-passenger seaplane, made a successful test flight in Canada.

Across Iowa wind turbines turned in the corn; tax credits have made them valuable income

IN 2007 A TORNADO WIPED OUT GREENSBURG, KANSAS. THE REBUILT TOWN RUNS ON RENEWABLE ENERGY—A RETURN TO THE SELF-RELIANCE OF PRAIRIE PIONEERS.

Detroit Hoist
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201

LEFT

Workers sand, paint, and polish wind turbine blades at TPI Composites' manufacturing plant in Newton, Iowa. Renewable energy reinvigorated Newton after the Maytag washer and dryer factory closed in 2007. In one former Maytag building, TPI produces electric bus bodies; in another, a company makes wind turbine towers.

NEXT PHOTO

Brian Caltrider harvests corn on the family farm near Adair, Iowa. MidAmerican Energy, the local utility, has added hundreds of wind turbines in Adair County since 2018, generating welcome revenue for farmers such as the Caltriders. Their corn was late in 2019 because of torrential spring rains—the kind of weather expected from climate change.

Grain Tank Full
OK

sources for farmers. Iowa is now second, after Kansas, in the portion of electricity it gets from renewables. In Newton, population 15,000, turbine towers are made in a former Maytag washing machine factory. In Montpelier, SSAB, a Swedish steel company, forges turbine parts. The massive heat comes not from coking coal, as in most steel mills, but from electric arc furnaces. In two years the furnaces will be powered entirely by clean energy, Chuck Schmitt of SSAB Americas told me. A steel mill in the heartland using wind to make wind turbine parts: It felt to us like a milestone.

AS A STUDENT at the Massachusetts Institute of Technology, Robert "RJ" Scaringe strung clotheslines in his apartment and did other "time-consuming and challenging" things to minimize his carbon footprint. Urging people to forfeit modern conveniences, he determined, wasn't a winning strategy. "It's too hard," he told us. Today Scaringe runs electric vehicle start-up Rivian, which plans to release a sport utility vehicle and a pickup this year. It also has a deal with retail giant Amazon to build 100,000 electric delivery trucks by 2030.

What's true of renewables is also true of electric vehicles: Things are changing fast, just not yet fast enough. Globally, there are five million electric cars, an increase of nearly two million in one year. Volkswagen alone plans to build 26 million more in 10 years. But that's in a world of roughly 1.5 billion cars and trucks. EVs are just 2 percent of the U.S. market.

Tesla isn't the only company trying to make EVs cooler. Ford has unveiled an electric Mustang, Harley-Davidson an electric motorcycle. But worldwide, drivers are favoring heavy, more polluting SUVs; there are now more than 200 million on the road, six times as many as in 2010. Scaringe is aiming for that market.

At Rivian's Plymouth, Michigan, engineering and design plant, we watched workers zip about on skateboards. Scaringe, 37, is focused on vehicles for active, outdoor lifestyles. He plans, with partners, to build high-speed charging stations in less traveled places, near the "edge of the trail." Much as teenagers can't imagine life before social media, Scaringe expects his own children—all under age five—will never know a world "where charging wasn't ubiquitous."

OVER THE NEXT FEW DAYS Guttenfelder and I raced toward our destination: Washington, D.C. We stopped in Ohio to tour First Solar, the biggest U.S. manufacturer of solar panels. In Pennsylvania we drove past the Three Mile Island nuclear plant. Forty years after the notorious accident that shut down its first reactor, the other one had just closed as well, because it is too expensive to run today. Seven other American nukes have shut down since 2013; seven more plan to by 2025. Much of their carbon-free electricity will be replaced by emissions-rich natural gas. The debate about the future of nuclear is complex and increasingly ideological.

So is the debate around climate change. "Unfortunately, for reasons that are hard to understand, sustainability has become a very political issue," Scaringe had told me. Yet policy shifts at all levels of government are needed to speed our transition to clean energy. Can a polarized nation be brought together around solutions?

Days before starting our trip, I'd visited a man who'd run for president proposing to do just that. On an afternoon when CNN was hosting town halls on climate with Democratic candidates, I'd driven a Nissan Leaf south from my Seattle home to Olympia, the state capital, to meet Washington governor Jay Inslee. Inslee had mapped out plans for everything from a national renewable energy policy for utilities to a zero-carbon building standard. But his presidential campaign never caught on, and he'd recently ended it.

Seemingly unbowed, he told me a story about the nation's ability to move quickly when the will is there. In 1940 the U.S. Army asked automakers to design a brand-new "light reconnaissance" vehicle. By the end of World War II, five years later, workers had built nearly 645,000 Jeeps.

"We are in a movie where we have not seen the final reel," Inslee said. "And we have the capability of having this be a happy ending."

A month after leaving Santa Monica, Guttenfelder and I arrived in Washington. Ducking into the National Museum of American History, I spotted Horatio Jackson's red Winton carriage—complete with a replica of Bud the bulldog in goggles. The exhibit, about American road trips, also highlighted an arduous 1919 cross-country convoy of military vehicles that had included a young lieutenant colonel, Dwight Eisenhower. Later, as president, Eisenhower would champion the interstate highway system.

A display nearby traced the history of how highways became necessary. Within a quarter century of Jackson's journey, cars had become

a fixture of American life. Twenty-three million roamed the U.S. by 1930, as Route 66 was being paved. More than half of American families owned one, maybe even some who'd initially dismissed them as "devil wagons."

Americans adapt quickly, once convinced that change is necessary, even useful. It could happen again. By 2070, clouds of "rolling coal" might be barely remembered wisps on the wind. ▯

Staff writer **Craig Welch** has covered the environment for a quarter century. Frequent contributor **David Guttenfelder** photographed opioid addicts in Philadelphia for the January issue.

This sign in Menlo, Iowa, was erected in 1934, on what was then U.S. Highway 6. Photographer David Guttenfelder drove by it often as a kid on the way to see his grandparents in Menlo. The gas station closed when I-80 diverted traffic south of town, but the sign, restored in 2008, waves again: Goodbye to the old car culture. Hello to something new.

FIGHTING FOR THEIR FUTURE

BY LAURA PARKER

AS CLIMATE CHANGE CREATES CHAOS WORLDWIDE, YOUNG PEOPLE ARE TAKING ACTION AND DEMANDING MORE FROM THEIR ELDERS.

DELANEY REYNOLDS, 20, IS FIVE FOOT TWO. WHEN SHE IS 60, SHE SAYS IN HER SPEECHES, SEA-LEVEL RISE IN HER HOME STATE OF FLORIDA WILL REACH HER WAIST. WHEN SHE'S 100, IT WILL BE FAR OVER HER HEAD. POINT MADE. "KIDS GET IT," SHE SAYS.

VICTORIA WILL

BEFORE GRETA, THERE WAS SEVERN.

Their photos often appear side by side, like bookends framing the long campaign by young people to persuade adults to take significant steps to fight climate change. Greta Thunberg, the Swedish teen activist, is the latest child to sound the alarm. Severn Cullis-Suzuki, the daughter of an environmental scientist in Vancouver, Canada, came first.

In 1992, when Severn was 12, she traveled with three other young activists to the United Nations climate conference in Rio de Janeiro. The science of global warming had just begun to resonate. The UN had created the Intergovernmental Panel on Climate Change, now the leading authority on climate science, just four years earlier, and world leaders weren't accustomed to listening to children lecture them.

Severn became known as "the girl who silenced the world for six minutes," setting a precedent for young activists to express their sense of impending doom in the clear-eyed way that only children can. "You must change your ways," Severn told the delegates. "Losing my future is not like losing an election or a few points on the stock market."

When Greta delivered her scold at the UN's climate summit in New York City last September, the similarities were striking. One could be forgiven for concluding that nothing at all had occurred in the intervening 27 years to stave off the existential threat to humanity.

Yet much has changed that might finally prompt action. The accelerating number and intensity of catastrophes not visible three decades ago has focused global attention on

‘OUR GENERATION IS TURNING THE CLIMATE CRISIS INTO HUMANITY’S MOST UNIFYING MOMENT.’

△

XIUHTEZCATL MARTINEZ

Martinez was born in Colorado and raised in the traditions of his indigenous Mexican heritage. At 19, he’s a hip-hop artist and youth director for Earth Guardians, a group that trains young environmental activists. He is one of 21 young people suing the U.S. government in a court case to secure their constitutional right to life and liberty by demanding action on climate change and a reduction in fossil fuel use.

VICTORIA WILL

GRETA THUNBERG

After capturing the world's attention at the United Nations in New York City last September, the activist, now 17, spoke in December at the UN's climate change conference in Madrid. Her main theme: science. "I've given many speeches and learned that when you talk in public, you should start with something personal or emotional to get everyone's attention," she said. "But today I will not do that because then those phrases are all that people focus on. They don't remember the facts, the very reason why I say those things in the first place."

TOM JAMIESON

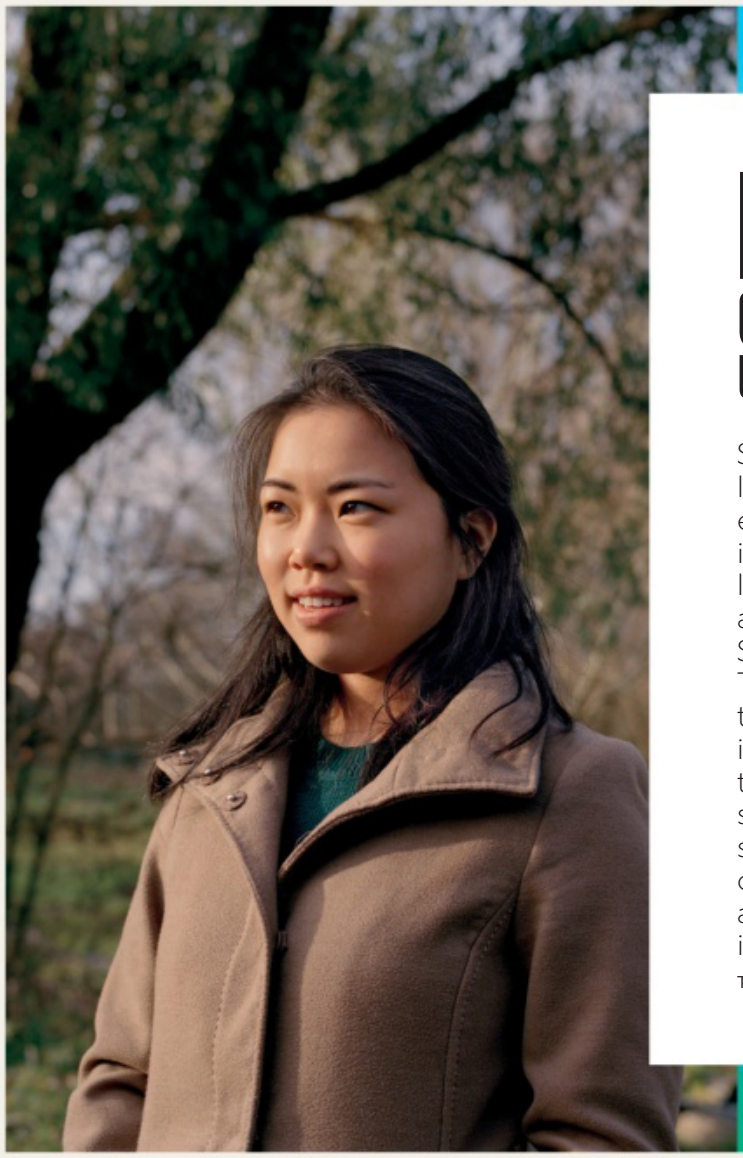
‘I STRONGLY BELIEVE IN A WASTE-FREE AND GREENER WORLD. JOIN US. TAKE ACTION. DO IT FOR YOUR OFFSPRING.’

△

GHISLAIN IRAKOZE

On a school assignment in Rwanda, Irakoze, 20, came upon an overflowing landfill in his hometown. He learned that discarded electronics create more than 50 million tons of waste globally each year. Now a university student, he founded Wastezon, which uses a mobile phone app to connect consumers with recycling industries. The company has helped send 460 tons of electronics to recyclers in Kigali, Rwanda’s capital.

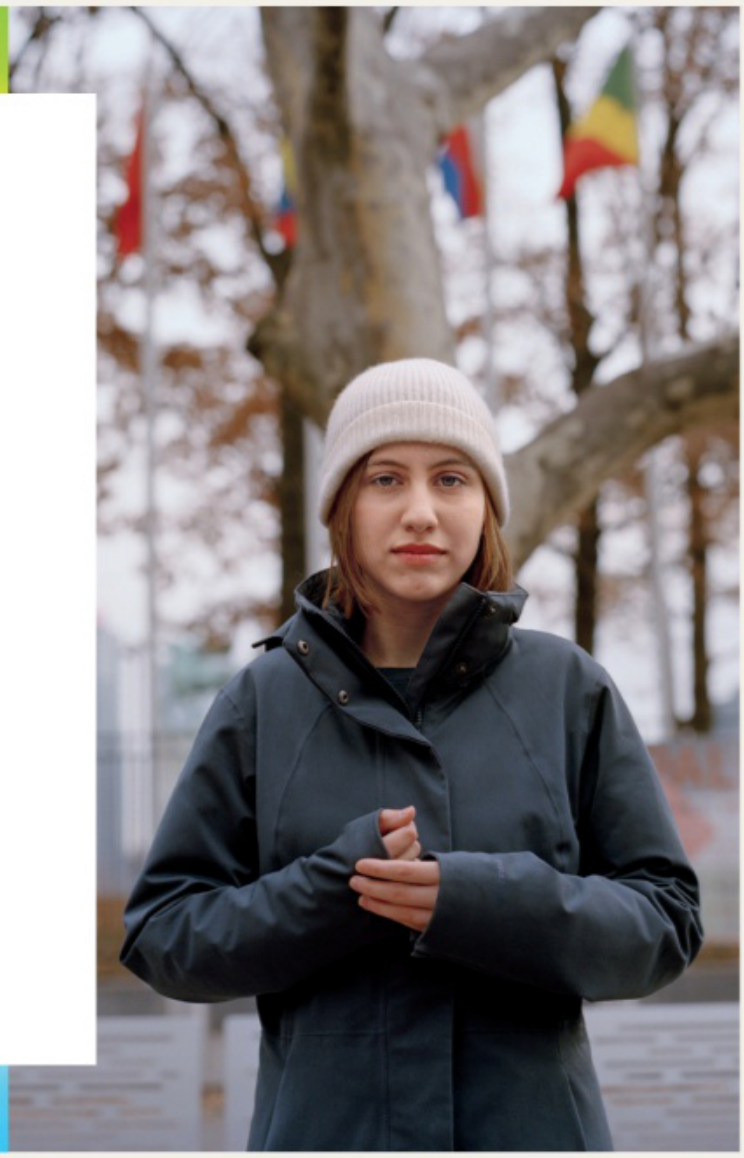
TOM JAMIESON



MAYUMI SATO

She has worked in Thailand, Laos, Nepal, and elsewhere on the social impacts of deforestation, landscape restoration, and climate mitigation. Sato, 25, is from suburban Tokyo but now studies in the U.K. "Climate change is not just an issue related to the environment," she says. "It exacerbates social exclusion, conflict, classism, racism. We all have to take part in climate justice."

TOM JAMIESON



ALEXANDRIA VILLASEÑOR

To show support for Greta Thunberg's school strikes in Stockholm, Villaseñor, then 13, began keeping her own Friday vigils outside the United Nations in New York City, where she lives. From that solitary beginning in December 2018, braving the cold rains, she's gone on to found Earth Uprising, a climate education group.

VICTORIA WILL

‘SCHOOL STRIKES WORK IN THE WESTERN WORLD. IN THE MAJORITY OF THE WORLD, THE PROBLEMS ARE DIFFERENT. IF THEY DON’T HAVE FOOD TO EAT, HOW ARE THEY GOING TO STRIKE?’

△

KEHKASHAN BASU

Born in Abu Dhabi of Indian heritage, Basu, 19, now lives in Toronto, Canada. A National Geographic Young Explorer, she started the Green Hope Foundation to give voice to young people. She helped children replant mangroves in the deforested Sundarbans on the Bay of Bengal and planted trees in a refugee camp in Bangladesh. Her optimism in the future is reflected in her foundation’s name.

REBECCA HALE, NGM STAFF

what's at stake. Tellingly, the population that will live with the consequences took to the streets last year to stage some of the largest environmental protests in history.

Young people are well positioned, by the strength of their numbers and the organizing power of social media, to provoke action. Worldwide, there are more than 3 billion people under 25, two-fifths of the total population. In the United States during the cultural unrest of the late 1960s and early 1970s, Americans between the ages of 18 and 29 numbered 41 million. Today the same age group is 52 million strong. Youth protests also have broadened into a movement that includes a mash-up of so many social causes, including racial justice and gun control, that it invites comparison with the social activism of the late 1960s that roiled countries around the world.

Millions of children have come of age watching ice sheets melt and temperatures rise, and they are fed up with waiting for government leaders to act. "The Vietnam War served as a trigger to radicalize a generation," says Stephen Zunes, a University of San Francisco political science professor. "Climate is going to do the same thing."

Delaney Reynolds, 20, who lives in Florida, one of the places most vulnerable to climate change, is increasingly frustrated with the lack of action. "A lot of adults in power today are way too focused on money and profits," she says. "As soon as we can replace them, we will replace them."

Now a student at the University of Miami, Reynolds grew up when Florida's leadership hadn't faced up to the flooding that will inevitably remake the coastline of their sandspit of a state; then Governor Rick Scott promoted an unofficial policy to avoid even mentioning the words "climate change." Reynolds founded the Sink or Swim Project and began educating Floridians about the risks of sea-level rise, giving hundreds of talks to everyone who would listen. "It is incredible that kindergartners can grasp this as a problem and politicians can't," she says.

Felix Finkbeiner, a 22-year-old German activist, is another old-timer in the youth climate change movement. He found his way to advocacy as a nine-year-old who had a toy polar bear and was moved by photos of starving polar bears struggling to hunt for food as the Arctic ice disappears.

Finkbeiner wanted to help: He planted a tree at his school. Now he's pursuing a doctorate in climate ecology while heading the nonprofit he founded in 2007. Plant-for-the-Planet has planted eight million trees in 73 countries and is part of a global effort to plant one trillion.

"There's no reason this movement had to wait this long or be a youth thing," he says. "What's happening is phenomenal. This could be the tipping point we were hoping for."

Last fall he met and shared tips with Lesein Mutunkei, a 15-year-old soccer player in Nairobi who planted a tree after every goal he scored to do his bit to help Kenya recover its forests. Mutunkei expanded his project to involve other youths who celebrate their own achievements by planting trees. "If you are good at music and reached a certain point, you can plant a tree for that. If you get an A in a subject, you can plant a tree," he says.

One of the most consequential efforts is playing out in the courts of the world, including in Norway and Pakistan, where young people are pursuing litigation to win climate protections. In a case that's ongoing, 21 young Americans have sued the federal government for its role in creating a "dangerous climate system."

THE MOST RECENT WAVE of climate protests began to build several years ago in Europe. Young activists in Germany organized school strikes that attracted few numbers and little attention but helped build the foundation for the movement sparked by Greta Thunberg's solitary school strike in August 2018, which swept the world. Unknown when she sat outside the Swedish parliament in Stockholm, the 17-year-old has become the face of a global movement that has seen school strikes in most countries and over 7,000 towns and cities. By the time she arrived in New York, after sailing across the Atlantic on a no-emissions yacht, she had achieved the kind of one-name celebrity usually afforded to rock stars.

Thunberg is plainspoken and blunt, perhaps in part because she has Asperger's syndrome. She doesn't engage in the contorted language so common in political discourse. When she testified before the U.S. Congress, she submitted a UN climate panel report instead of prepared remarks. "I don't want you to listen to me, I want you to listen to the scientists," she said.

Elizabeth Wilson, a human rights lawyer and visiting scholar at Rutgers Law School in New Jersey, has watched young activists find their footing. "I think it is extraordinary where

we have persuaded ourselves we're living in a post-truth world, and these kids are saying, 'We believe in facts. We believe in science. What you are telling us is not an alternative reality; it's a lie,'" she says. "It's breathtaking."

It's easy to forget that, for all their media savvy and tactical organizing skills, many of the climate activists are still just children. Many struggle with anxiety and depression. Their attention is riveted on alarming reports—a 2018 UN analysis that concluded carbon emissions must be cut almost in half by 2030 to hold global warming to 1.5 degrees Celsius (2.7 degrees Fahrenheit), and research by the World Meteorological Organization and the journal *Nature* published late last year warning that temperatures rising beyond that threshold will lead to worsening hurricanes, floods, droughts, and wildfires, as well as agricultural disasters that could shrink the world's food supply.

"It's not hard to find kids who say they don't want to have children because of the chaos they believe the world will be in," says Lise Van Susteren, a psychiatrist who has studied how youth are coping with climate change. "This is a shaky time for children. They have seen it for themselves. They have seen the fires. They have seen the storms. They're not stupid, and they are angry."

Alexandria Villaseñor, 14, who has skipped school on Fridays since December 2018 to strike at UN headquarters in New York, and Jamie Margolin, 18, founder of the group Zero Hour, candidly described their fears for the future at a symposium last fall at Twitter's Washington, D.C., office. Villaseñor said she's worried that, by the time she's able to vote and help elect leaders who will act on climate change, it will already be too late. Margolin, who lives in Seattle, described bouts of despair that have sent her to bed. "Climate anxiety is real for me," she said.

WILL THE MOVEMENT finally succeed? History argues against it. Social movements waged against identifiable villains, such as despots, often succeed. But it's more difficult to force societies to make structural changes, which can consume decades. Remaking the world's energy system presents an almost Sisyphean task.

"The hallmarks of a movement that is going to be successful are sustaining it and turning it into public policy," says Kathleen Rogers, president of the Earth Day Network and a longtime environmental activist. "If you don't turn it into political power, it will just die."

In Europe, activists have changed the political landscape more easily than they have in the United States. "In Germany, there has been a fundamental shift in policy and scale," Finkbeiner says. "Every German politician has understood that elections can no longer be won without green policies."

Severn Cullis-Suzuki, now 40, doesn't fear the climate movement will fizzle. "What strikes me now is how much right now feels like where we were back in 1992. Rio was a success. We got all the leaders to sign on," she says. "We're back at that same moment. Awareness has been raised. We now have to translate that into nothing short of a revolution."

> 'IT IS INCREDIBLE THAT KINDERGARTNERS CAN GRASP THIS AS A PROBLEM AND POLITICIANS CAN'T.'
> **DELANEY REYNOLDS**

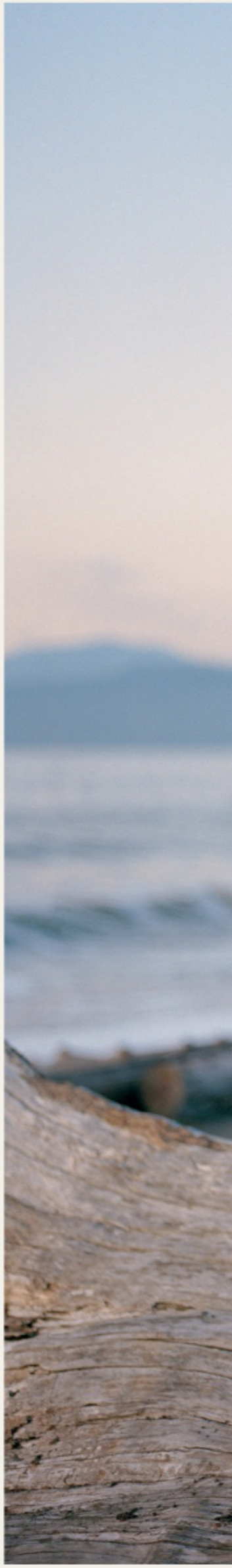
Cullis-Suzuki, who earned a degree in ecology, now lives with her husband and two children on Haida Gwaii, an island cluster off the coast of British Columbia, Canada. She's working on a doctorate in linguistic anthropology, studying the language and culture of the Haida, an indigenous people whose stewardship of their environment has enabled them to endure for more than 10,000 years. She pauses. Does she need to say more? □

Staff writer **Laura Parker** covers climate change and marine environments. Her last feature article in the magazine, in May 2019, was about how microplastics are harming fish in the ocean.

ROSIE MILLS

Mills, 19, led a petition drive that persuaded the local council in Lancaster, England, to declare a "climate emergency" after catastrophic flooding. Last year she ran for a seat in the European Parliament as a Green Party candidate. She lost, but didn't finish last. "One of the weirdest things is when a teacher comes up to you and says, 'I'm going to vote for you.' Then she assigned me an essay the next day."

TOM JAMIESON



‘THE YOUNGER GENERATION NEEDS TO SEE HOW TO ACT IN CRISIS. ARE WE GOING TO SCREAM OUR HEADS OFF AND FREAK OUT? WHAT WE NEED IS CALM AND STEADY AND VERY CLEAR ACTION, AND THAT’S HOW TO BE PARTNERS ACROSS GENERATIONS.’

△

SEVERN CULLIS-SUZUKI

Through speaking, writing, and filmmaking, she promotes a return to values that will sustain the Earth. Her 1992 speech to the UN climate conference in Rio de Janeiro, delivered when Cullis-Suzuki was 12, stills draws viewers on YouTube. In 2017 she celebrated its 25th anniversary by encouraging young people to give her speech, or parts of it, and to upload the video to her “I’m Only a Child, but …” YouTube page.

KARI MEDIG

FELIX FINKBEINER

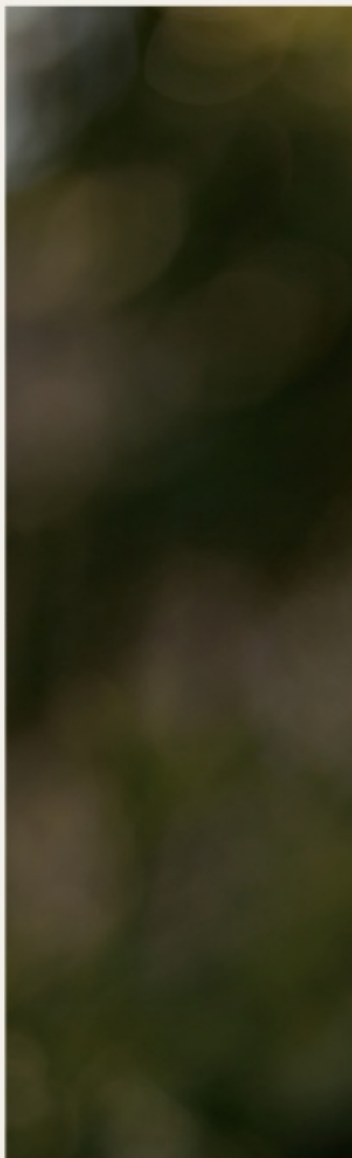
Finkbeiner, 22, a National Geographic Young Explorer, founded a tree-planting nonprofit in his German village in 2007, when he was just nine. Plant-for-the-Planet's workshops, which teach children about global warming, have created an army of more than 93,000 "climate justice ambassadors" who have become activists in their communities.

DANA SCRUGGS

RABAB ALI

Ali, 11 (shown with her brother, Ali Monis, seven), has sued the Pakistani government, asserting that it has violated her generation's right to live in a healthy environment by allowing damage from mining and from burning fossil fuels, namely coal. She won a decision affirming that juveniles have a right to sue. Ali's father, an environmental lawyer, filed the claim on her behalf.

HUMAYUN MEMON



‘POLITICIANS CARE ABOUT BEING REELECTED, AND THAT COMES WITH VOTING AND WITH MONEY. YOUNG ACTIVISTS DON’T HAVE MUCH MONEY, BUT WE DO HAVE A MASSIVE NUMBER OF YOUNG VOTERS WHO ARE NOT REGISTERED.’

△

JEROME FOSTER II

He’ll be old enough this November to vote for the first time in a U.S. presidential election, and he sees registering young people to vote as the best way to spur action on climate change. To do that, the Washington, D.C., resident founded OneMillionOfUs. His organization combines voter registration with activism on climate change, gun control, immigration reform, and gender and racial equality.

REBECCA HALE, NGM STAFF

EARTH DAY 2070

FIFTY YEARS OF PROGRESS AND DAMAGE

IN WEALTHY COUNTRIES, THE AIR, WATER, AND LAND ARE CLEANER THAN 50 YEARS AGO. THE TASK AHEAD: EXPAND THAT SUCCESS, DEVELOP CLEAN ENERGY, AND CONSERVE AS NEVER BEFORE.

△

▽

THE CRISIS IS GLOBAL: A RAPIDLY WARMING CLIMATE, ACCELERATING EXTINCTION RATES, AND A GROWING POPULATION ENCROACHING EVER FURTHER ON NATURE.

1970s

1970 FIRST EARTH DAY ▲
On April 22, an estimated 20 million people march in U.S. streets to call attention to the urgent need for environmental protections.

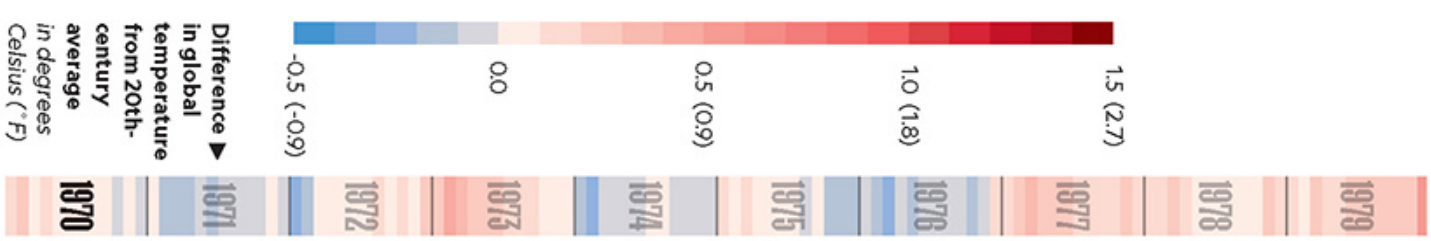
1972 U.S. BANS NOTORIOUS PESTICIDE ▲
Silent Spring had called for it; the new EPA does it: DDT is declared to be dangerous to wildlife, the environment, and potentially humans.

1970 "ENVIRONMENTAL MAGNA CARTA"
The National Environmental Policy Act takes effect in the U.S. It requires environmental impact assessments for federally permitted projects such as roads and dams.

WORLD POPULATION IN 1970 3.7 BILLION

1972 CLEANING UP RIVERS
The Clean Water Act regulates pollution and leads to major cleanups in U.S. rivers, streams, lakes, wetlands, and coastal areas. Some even become fishable and swimmable again.

1972 DEFENDING MARINE MAMMALS ▲
The Marine Mammal Protection Act shields declining populations—whales, dolphins, seals, and manatees—from hunting and harassment in U.S. waters. Their numbers begin a decades-long recovery.



1973 SAVING SPECIES ▲
The Endangered Species Act limits encroachment on the habitat of listed animals and plants. It prevents extinctions—but is attacked for infringing on property rights.

1976 CHEMICAL PLANT ACCIDENT IN SEVESO, ITALY ◀
Toxic vapors expose thousands of people to some of the highest dioxin levels ever recorded.

1978 LOVE CANAL FUROR
Buried toxic chemicals sicken hundreds of residents in the community of Love Canal, near Niagara Falls, New York, calling attention to the dangers of industrial waste.

1979 THREE MILE ISLAND
A partial meltdown at a Pennsylvania nuclear power plant kills no one—but sours many Americans on nukes.

1980s

1980 ALASKA WILDLANDS PROTECTED

The Alaska National Interest Lands Conservation Act sets aside more than 100 million acres of wilderness in national parks, preserves, and refuges.

WORLD POPULATION IN 1980

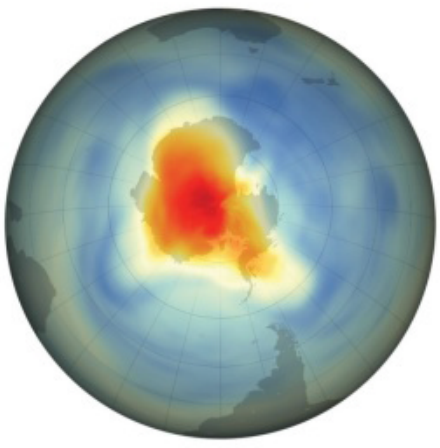
4.5 BILLION

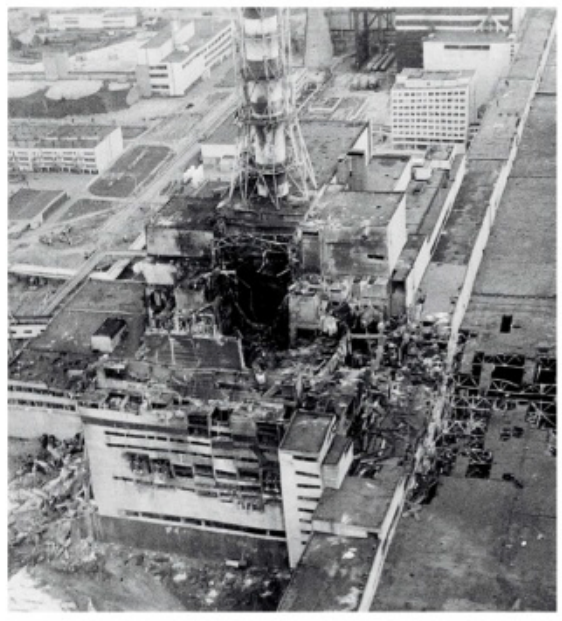
1980 SUPERFUND PROGRAM IS LAUNCHED IN U.S.

The fund enables the U.S. Environmental Protection Agency to clean up hazardous waste sites. Polluters must perform the cleanup or pay for it.

1985 DISCOVERY OF THE OZONE HOLE

Scientists detect severe depletion (red) of the protective ozone layer above Antarctica. The culprits: chlorofluorocarbons and other chemicals.





1986 CHERNOBYL NUCLEAR ACCIDENT

A nuclear reactor explodes at the Chernobyl power plant in the Soviet Union. The blast and radiation kill 30 and force the evacuation of nearly 1,100 square miles—raising more doubts about nuclear power.

1987 MONTREAL PROTOCOL

World leaders agree to phase out ozone-depleting substances just a few years after the ozone hole is found. All nations ratify the treaty.

1987 RESCUING CONDORS

The last 27 California condors are taken into captivity for breeding. A long recovery begins; today more than 200 live in the wild once again.

1988 GREENHOUSE EFFECT DETECTED

NASA climatologist James Hansen tells the U.S. Congress that carbon dioxide and other heat-trapping gases released by the burning of fossil fuels are already warming the planet.

1989 *EXXON VALDEZ*

The supertanker spills 11 million gallons of crude oil into Prince William Sound, Alaska.

1990s

1990 BAN ON INTERNATIONAL TRADE IN ELEPHANT IVORY ▲
It briefly slows poaching of African elephants. By 2016 Kenya is burning ivory to deter poaching.

1991 BRINGING FERRETS BACK ▲
Black-footed ferrets, once extinct in the wild, are reintroduced to the American West by U.S. Fish and Wildlife Service scientists after a captive-breeding program. They remain endangered.

1991 KUWAIT OIL FIRES
As the Persian Gulf War winds down, Iraq sets more than 600 Kuwaiti oil wells on fire. Some 1.5 billion barrels of oil are burned or spilled.

1995 WOLVES RETURN TO YELLOWSTONE
Reintroduced to the national park, gray wolves help rebalance an ecosystem suffering from an overpopulation of elk.

1995 AMAZON FOREST LOSS
The deforestation rate rises dramatically, mostly to create cattle pasture, presaging a surge in Brazilian beef exports. Beef becomes a prime driver of rainforest destruction.

WORLD POPULATION IN 1990
5.3 BILLION

1990 FIRST IPCC PROJECTION
The UN's Intergovernmental Panel on Climate Change issues its initial global warming report. Over the next quarter century, its forecasts mostly come true.

1990 FIGHTING ACID RAIN
Amendments to the U.S. Clean Air Act help reduce acid rain and ozone depletion, require cleaner gasoline, and target toxic emissions and urban air pollution.

1995 BALD EAGLE RECOVERY ▲
The American national bird is reclassified from endangered to merely threatened. Later it is delisted completely—one of about 90 animal and plant species so far to reach that goal.

1990 1991 1992 1993 1994 1995 1996 1997 1998 1999

1996 LEADED GAS BAN IN U.S. ▲
It caps a long phaseout that caused blood lead levels to plummet. Most of Europe follows in 2000.

1997 AMPHIBIAN APOCALYPSE ◀
Scientists confirm that the chytrid fungus spread by humans has been killing hundreds of types of amphibians.

1997 KYOTO PROTOCOL
To address climate change, 37 nations and the European Community pledge to cut CO_2 emissions. The U.S. later fails to ratify the treaty.

1999 GOLDEN RICE ▼
Rice is genetically engineered with vitamin A to boost nutrition in the diets of Africans and Asians.

2000s

WORLD POPULATION IN 2000

6.1 BILLION

2000 THE HYBRID REVOLUTION

Toyota's Prius, the first mass-produced car with both a gasoline engine and an electric motor, arrives in the U.S. and becomes an icon of fuel efficiency.

2002 CALIFORNIA GOES SOLAR ◀

The state commits to getting 20 percent of its electricity from renewables by 2017. It exceeds the target—and raises it to 100 percent by 2045.

2002 LARSEN B ICE SHELF COLLAPSES

A NASA satellite documents the breakup in a month of a 1,250-square-mile ice shelf floating off the rapidly warming Antarctic Peninsula.

2005 HURRICANE KATRINA

America's costliest storm kills 1,833 people and floods 80 percent of New Orleans.

2006 SHARK FINNING

Scientists calculate that 26 million to 73 million sharks are killed annually for their fins. The shocking numbers raise alarm about shark populations.

2006 AL GORE'S MOVIE ▶

An Inconvenient Truth helps raise public awareness about the threat of climate change and wins an Academy Award for best documentary feature. But the moment passes without significant progress in addressing the threat.

2006 TOXIC WASTE IN CÔTE D'IVOIRE

Waste containing hydrogen sulphide and other chemicals is dumped near the port city of Abidjan. It kills 15 and sickens 100,000.

2006 CHINA RISING

With soaring coal use fueling a booming economy, China passes the U.S. to become the largest emitter of CO_2. Its per capita emissions remain far lower.

2006 HONEYBEE COLONIES COLLAPSE ◀

Beekeepers begin reporting the mysterious disappearance of worker bees, which is leading to the collapse of many colonies.

2006 WHITE-NOSE SYNDROME ▶

A fungus starts killing millions of American bats of several species, including endangered little brown bats.

Difference in global temperature from 20th-century average *in degrees Celsius (°F)* ▶

-0.5 (-0.9) | 0.0 | 0.5 (0.9) | 1.0 (1.8) | 1.5 (2.7)

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

2008 ELECTRIC CARS GET COOL ▲

Tesla Motors, founded in 2003, releases its first car, the completely electric two-door Roadster. In company tests, the sports car travels 245 miles on a single charge, an unprecedented range for a mass-produced electric car.

2008 GLOBAL SEED BANK ◀

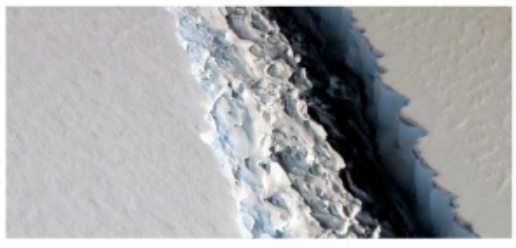
The Svalbard Global Seed Vault opens deep inside an Arctic mountain. Operated by Norway, it can store the frozen seeds of up to 4.5 million crops as an insurance policy for future generations.

2010s

WORLD POPULATION IN 2018 **7.6 BILLION**

2010 DEEPWATER HORIZON OIL SPILL ▲
An oil rig explosion kills 11 workers and spews more than 130 million gallons of oil into the Gulf of Mexico, the largest spill in U.S. history.

2016 MAMMAL EXTINCTION
It's the first caused by climate change: the Bramble Cay melomys, an Australian rodent.



2016 LARSEN C ICE SHELF CRACKS ▲
After the Larsen B collapse in 2002, the next massive ice shelf on the Antarctic Peninsula begins to crack—just as expected from climate change.

2011 FUKUSHIMA DISASTER
An earthquake and a tsunami trigger the partial meltdown of three reactors at a Japanese power plant and massive discharges of radioactive material into the air and sea.

2012 HURRICANE SANDY
New York floods; damages reach $73 billion.

2012 ARCTIC SEA ICE EXTENT
It shrinks in September to a record minimum, about two Alaska-areas less than average.

2015 PARIS CLIMATE AGREEMENT
Leaders of 195 nations agree to cap global warming at two degrees Celsius. Many countries later announce emissions cuts—though not enough to meet the two-degree goal. President Donald Trump announces that the U.S. will withdraw.

2017 U.K. COAL DECLINE
For the first time since the 1880s, the home of the industrial revolution goes a day without making electricity from coal. The government aims to shut all coal plants by 2025.

2019 AUSTRALIAN WILDFIRES ▲
They burn an area larger than Iceland, killing up to a billion animals.

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019

2019 MEATLESS BURGERS ▲
...hit the mainstream.

2019 AMAZON RAINFOREST WILDFIRES ▼
Fires linked to deforestation blanket much of Brazil in smoke, stoking fears that parts of the rainforest could turn to dry savanna.

2020 EARTH DAY TURNS 50

2020 EARTH DAY TURNS 50

PHOTOS (FROM 1970S): NASA (EARTH); JAMES P. BLAIR (DDT); ALASKA STOCK IMAGES/NATIONAL GEOGRAPHIC IMAGE COLLECTION (WHALE); JIM AND JAMIE DUTCHER, NATIONAL GEOGRAPHIC CREATIVE (WOLF); MARKA, GETTY IMAGES (PESTICIDE PLANT); MICHAEL MELFORD (SUPERFUND); JOEL SARTORE, NAT GEO PHOTO ARK (CONDOR); AP IMAGES (CHERNOBYL); NASA (OZONE); NATALIE B. FOBES *(EXXON);* CHARLIE HAMILTON JAMES (IVORY); JOHN EASTCOTT AND YVA MOMATIUK, NGIC (EAGLE); SARAH LEEN (GAS PUMPS); JOEL SARTORE, NAT GEO PHOTO ARK (FERRET); CRAIG CUTLER (RICE); JOEL SARTORE (FROGS); PARAMOUNT CLASSICS, PHOTOFEST (INCONVENIENT TRUTH); DAVID GUTTENFELDER (SOLAR PANELS); NATIONAL MOTOR MUSEUM, GETTY IMAGES (TESLA); JIM RICHARDSON (SEED BANK); INGO ARNDT (BEE); STEPHEN ALVAREZ (BAT); LAURI PATTERSON, GETTY IMAGES (BURGER); CHARLIE RIEDEL, AP PHOTO (OIL SPILL); NASA EARTH OBSERVATORY, JOHN SONNTAG (LARSEN C); MATTHEW ABBOTT, *NEW YORK TIMES* (AUSTRALIA); VICTOR MORIYAMA, GETTY IMAGES (AMAZON)

CHART BY NGM STAFF. SOURCE: NOAA

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THE PESSIMIST'S GUIDE TO

EARTH DAY 2070

FIFTY YEARS AGO WE CELEBRATED THE FIRST EARTH DAY. WHERE WILL WE BE 50 YEARS FROM NOW? OUTLOOK: NOT SO GOOD.

▽

Not feeling pessimistic? Flip the magazine for an optimist's guide, including a look at an electric-car road trip and promising young activists.

—

ART BY ANDY GILMORE

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THE CASE FOR CATASTROPHE

The world will be a much more dangerous place, where flooding, drought, fire, and unrest have forced millions from their homes.

BY ELIZABETH KOLBERT

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A WORLD LOST

Losing a landscape—through climate change, disaster, or development—takes an emotional toll.

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THE WORLD IN 2070

In the next 50 years, our environment is set to change drastically.

BY KAYA LEE BERNE, ALEJANDRA BORUNDA, RILEY D. CHAMPINE, AND JASON TREAT

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FIFTY YEARS OF DAMAGE

The recent fires across Australia are one of many signs over the past five decades that Earth and its inhabitants are in the midst of a crisis.

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Unchecked climate change will hit Africa especially hard.
IMAGINARY FORCES

PHOTO: MATTHEW ABBOTT, *NEW YORK TIMES*

Koala
Phascolarctos cinereus

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NATIONAL GEOGRAPHIC
EarthDay

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PHOTO BY JOEL SARTORE / NATIONAL GEOGRAPHIC PHOTO ARK

NUCLEAR SETBACK

A tourist in Chernobyl, Ukraine, dons a gas mask to snap a selfie near the containment shell surrounding the nuclear reactor that exploded in 1986. Radiation—revealed in this composite image by a unique gamma camera—still emanates from contaminated materials, but visiting for brief periods is safe. Chernobyl helped dim prospects for nuclear power, a carbon-free energy source.

MIKE HETTWER
(WITH WILLY KAYE, H3D)

WE'RE IN TROUBLE

OUR RECKLESS CONSUMPTION AND ABUSE OF RESOURCES HAVE MADE THE WORLD A DEADLIER PLACE FOR US—AND FOR THE REST OF LIFE ON EARTH.

PLASTIC THREAT

Indo-Pacific sergeants swim around a plastic bag near Taiwan. An estimated 8.8 million tons of plastic waste enters the ocean each year, killing millions of marine animals.

MAGNUS LUNDGREN, NATURE PICTURE LIBRARY

BIGGER BLAZES

Men dodge embers as they try to save a house in Ventura, California, during the 2017 Thomas fire. Burning a thousand structures and 280,000 acres, the fire was the state's largest—but only briefly. In California and beyond, a warmer, drier climate is fueling ever bigger fires.

MARCUS YAM, *LOS ANGELES TIMES*

LOSING THEIR PLACE

A jaguar's image is projected onto a fence along the U.S.-Mexico border—the photographer's effort to call attention to how such barriers can jeopardize wildlife by blocking access to habitat. A quarter of all mammals are threatened with extinction.

ALEJANDRO PRIETO

COAL'S IMPACT

A family celebrates a wedding in the shadow of a coal plant in Datong, China. Coal is the single biggest source of global temperature increases, with China accounting for half the world's yearly consumption.

ADAM DEAN, PANOS

ON THE 50TH ANNIVERSARY OF EARTH DAY, WE ASK: WHERE WILL WE BE IN 2070?

PESSIMIST'S GUIDE

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NATIONAL GEOGRAPHIC | VOL. 237 NO. 4

THE CASE FOR CATASTROPHE

OUR FAILURE TO ADDRESS CLIMATE CHANGE IS TRASHING THE PLANET. INNOVATION MAY SAVE US, BUT IT WON'T BE PRETTY.

BY ELIZABETH KOLBERT

"A UNIQUE DAY IN AMERICAN HISTORY is ending," Walter Cronkite intoned on the *CBS Evening News* on April 22, 1970. The inaugural celebration of Earth Day had drawn some 20 million people to the streets—one of every 10 Americans and a way bigger crowd than the man who'd dreamed up the occasion, U.S. senator Gaylord Nelson, had anticipated. Participants expressed their concern for the environment in exuberant, often idiosyncratic ways. They sang, danced, donned gas masks, and picked up litter. In New York City they dragged dead fish through the streets. In

PREVIOUS PAGE: The work of California artist Shane Grammer adorns the ruins of the Seventh-day Adventist church in Paradise, California. The November 2018 Camp fire, whipped by heavy winds from a small brush fire into an inferno, destroyed almost the entire town. As the climate changes, warmer temperatures, reduced snowpack, and earlier spring snowmelt create longer dry seasons, which stress plants and trees. Dry forests and brush help fuel larger wildfires, making communities in fire-prone areas more vulnerable.

STUART PALLEY

Lessons to learn

A college student wearing a gas mask "sniffs" a magnolia blossom in New York City as part of a demonstration on April 22, 1970—the first Earth Day. Local events were designed to educate and raise awareness as Americans grew concerned about environmental issues such as pollution and chemical waste disposal. According to a White House poll taken a year later, 25 percent of the U.S. public said protecting the environment was an important goal. In 1969 the number had been close to zero.

AP PHOTO

Boston they staged a "die-in" at Logan International Airport. In Philadelphia they signed an oversize, all-species "Declaration of Interdependence."

"Earth Day did exactly what I had hoped for," Nelson, a Democrat from Wisconsin, would say later. "It was truly an astonishing grassroots explosion."

I'm old enough to have been around for the first Earth Day, and though I have no recollection of having joined in the festivities, I'm very much a product of that "unique" moment, with its die-ins and its declarations. I spent the seventies protesting in the rain, trying to persuade my classmates to recycle their soda cans, wearing bell-bottoms printed with giant purple flowers, and worrying about the future of the planet.

As an adult, I became a journalist whose beat is the environment. In a way, I've turned my youthful preoccupations into a profession. I've traveled to the Amazon to report on deforestation, to New Zealand to see the impacts of invasive species, and to Greenland to accompany scientists drilling through the melting ice sheet. I've also had kids. I watched with pride when they joined their school's environmental club and recounted to them—perhaps once or twice too often—my memories of pulling recyclables from the trash in my school cafeteria.

I now live in New England, where April 22 can be a glorious day. The trees are starting to bud, the spring peepers are calling, the phoebes are building their nests. Every year on Earth Day, I try to go for a hike in the woods near my house. I look for tadpoles and admire the spring ephemerals. And every year I grow more worried about the planet's future.

IF, ON THE FIRST EARTH DAY, instead of watching Walter Cronkite on CBS, you'd tuned in to NBC, you would have heard one of that network's anchors, Frank Blair, deliver a curious message. Toward the end of his report on the festivities, Blair noted that a government scientist named J. Murray Mitchell had issued an "awesome Earth Day warning." Blair summarized the warning this way: Unless something were done to reduce air pollution, it would "create a greenhouse effect" that would warm the entire planet. Eventually the effect would be enough to melt the Arctic ice cap and flood "vast areas of the world."

Probably not many viewers had any idea what Blair was talking about. In 1970 the term "global warming" had yet to be coined. Scientists knew that certain gases, including carbon dioxide, trap heat near the surface of the Earth; this had been understood since the Victorian era. But only a few had tried to calculate what the impact of burning fossil fuels would be. Climate modeling was in its infancy.

The models have since become much more sophisticated. And though many Americans still willfully refuse to accept the science of climate change, we all now live with its consequences.

The perennial Arctic ice cap—the sea ice that persists through winter and summer—is wasting away. Over the past half century it has shrunk by more than a million square miles. Sea levels are rising ever faster, largely thanks to accelerating melt from Greenland and Antarctica.

Increasingly, low-lying coastal cities in the United States are experiencing what's known as sunny-day flooding, when all it takes is a high

tide to send water gushing into the streets. According to projections from the National Oceanic and Atmospheric Administration, this sort of flooding will, a few decades from now, be the norm in cities such as Miami, Florida, and Charleston, South Carolina. By 2050, Norfolk, Virginia, is expected to experience high-tide flooding nearly half the days of the year.

And the kind of sea-level rise that will make life difficult in places like Norfolk is apt to make it impossible in places like the Marshall Islands and the Maldives. A recent study by American and Dutch researchers predicted that by the middle of this century, most atolls would be uninhabitable.

Flooding, meanwhile, is just one of the unfortunate consequences of fiddling with the planet's thermostat. A warmer world is also racked by deeper droughts, fiercer storms, and more erratic monsoons. It's a world where the wildfire season lasts longer and the blazes grow bigger and more intense.

Before 1970, megafires—fires that consume at least 100,000 acres—were rare in the United States. In the past decade, there have been dozens. In the summer of 2019, forest fire burned through more than 17 million acres in Siberia; this is an area nearly as large as Ireland. Smoke engulfed the region in a sickly haze and prompted health officials to advise residents of cities such as Krasnoyarsk to venture outside only if absolutely necessary. In late 2019 and early 2020, fires in Australia ravaged tens of millions of acres.

And that's not all. Land degradation, coral bleaching, increasingly deadly heat waves, the expansion of marine dead zones—these are all happening now. I could go on and on listing the dangerous impacts of climate change, but then you might stop reading. My point is: We're already seeing a great deal of damage, and it's increasing year by year.

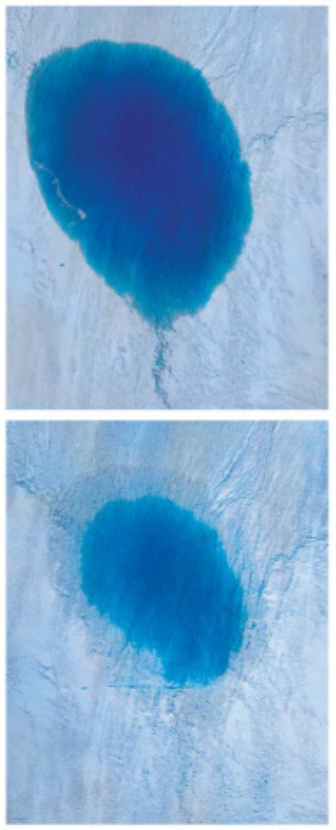
In 2070, when Earth Day turns 100, what will the Earth look like? This clearly depends on how much carbon we emit between now and then. (Just in the roughly 10 minutes it takes you to read this article, more than a half million tons of CO_2 will be added to the atmosphere.) But to a disturbing extent, the future has already been written.

THE FIRST EARTH DAY was such a grassroots explosion that just about every media outlet wanted in on it. The *Today* show ran a whole week of special programming with the theme "New World or No World." The show's host, Hugh Downs, opened the week with this assessment: "Our Mother Earth is rotting with the residue of our good life. Our oceans are dying, our air is poisoned."

"Do we have the will to turn our way of life upside down?—because that is what it is going to take," Downs continued. "Or do we go on breeding, demanding more and more power, more of everything until we suffocate or die of plague or famine? Probably within the next century, possibly within the next couple of decades?"

In 1970 the planet was home to 3.7 billion people. There were some 200 million cars and trucks on the road; oil consumption was around 45 million barrels a day. That year, people collectively raised about 36 million tons of pork and 14 million tons of poultry, and harvested around 65 million metric tons of seafood.

Today there are nearly eight billion people and some 1.5 billion vehicles on the planet. Global oil consumption has more than doubled, as has power use. Pork consumption per capita has almost doubled, poultry consumption has nearly quadrupled. The global wild fish catch has increased by about half, even as overfishing has made fish harder to find. In other words, to borrow from Downs, we kept "demanding more and more."



Greenland meltdown

As summers warm, meltwater lakes are multiplying on the Greenland ice sheet. These before and after drone images show how one 300-acre lake drained almost completely in 2018 when a crack opened in the ice; at one point it was losing an Olympic pool's worth every three seconds. Water from such lakes flows to the bottom of the ice sheet, where it lubricates the bedrock and speeds the flow of ice into the ocean—adding to rising seas.

COMPOSITE IMAGES: TOM CHUDLEY, UNIVERSITY OF CAMBRIDGE

And yet people haven't just survived; by most measures, they've thrived. Globally, life expectancy has increased from 59 years in 1970 to 72 years today. Even as the number of people on the planet has more than doubled, the number of people living in extreme poverty has been cut in half.

With hindsight, it's easy see why Downs's predictions were off. They failed to anticipate breakthroughs such as the green revolution, which spread new plant varieties and farming techniques and allowed increases in grain production over the past 50 years to outpace increases in population. In 1970 aquaculture barely existed. It now produces some hundred million metric tons of fish annually.

EVEN IF WE WERE TO START CUTTING EMISSIONS TODAY, THE PROBLEM OF CLIMATE CHANGE WOULD CONTINUE TO GROW.

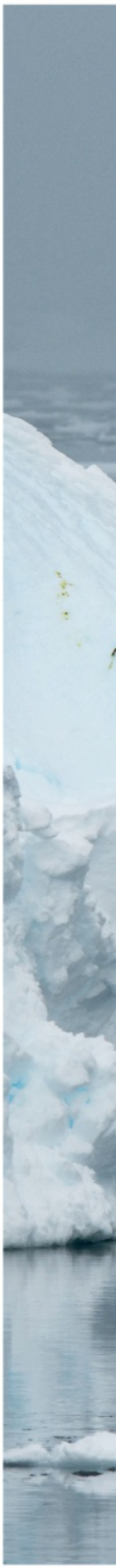
And Earth Day itself spurred change. Just seven months after millions of Americans took to the streets, the Environmental Protection Agency was created. Many of the country's major environmental laws, including the Clean Water Act, the Endangered Species Act, and key amendments to the Clean Air Act, were approved by Congress within the next few years. These, in turn, led to the development of technologies, like scrubbers to clean the stack gases of power plants.

So why not assume that the same sorts of innovations—both technological and social—will spare us from a future immiserated by global warming? Certainly, I believe that there will be many breakthroughs between now and 2070. In the course of my reporting, I've driven cars that emit only water vapor as a waste product and seen machines that suck carbon dioxide out of the air. Inventions I can't begin to imagine are doubtless on the way.

Unfortunately, though, climate change is a special kind of problem. Carbon dioxide hangs around in the atmosphere for centuries, even millennia. This means that even if we were to start cutting emissions today, the amount of CO_2 in the atmosphere and the problem of climate change would continue to grow—just as the water level in a bathtub will continue to rise if you reduce but don't shut off the flow from the tap. Earth will keep warming until we shut down emissions completely.

Meanwhile, we've yet to experience the full effects of the CO_2 we've already emitted, mostly because it takes the huge oceans a long time to warm up in response to a given level of CO_2. Average global temperatures have risen by about 1 degree Celsius (nearly 2 degrees Fahrenheit) since the 1880s, but owing to the time lag in the system, scientists estimate we're committed to another half a degree or so Celsius (almost a degree Fahrenheit). As far as climate change is concerned, it's always later than it seems.

How hot can it get before truly catastrophic changes are set in motion? (To cite one such potential change, were the Greenland ice sheet to melt away entirely, global sea levels would rise by about 20 feet.) Scientists warn that the threshold is probably about 2 degrees Celsius warmer than preindustrial times and perhaps even 1.5 degrees. Because temperatures already have risen about a degree and there's another half a degree of "commitment," we're all but assured of passing 1.5 degrees. To keep temperatures under the 2-degree threshold, global emissions would have to drop by at least half over the next few decades, and all the way to zero by 2070 or so.



Dive to survive

Emperor penguins normally breed on sea ice, taking more than eight months to raise their chicks. When sea ice is unstable or breaks up before the chicks fledge, emperors sometimes move onto the continent's more stable ice shelf. Fledglings then have to leap from great heights to feed in the ocean. Sea ice is projected to decrease as oceans warm. If the penguins don't adapt, their population could plunge dramatically.

STEFAN CHRISTMANN

In theory, this is possible. Most—perhaps all—of the world's fossil fuel infrastructure could be replaced by solar cells, wind turbines, and nuclear power plants. In practice, the tremendous boom in wind and solar that's under way has not reduced our use of fossil fuels, because we keep demanding more and more energy. Even as the impacts of climate change become increasingly vivid, global emissions continue to rise. In 2019 they hit a new record of 43.1 billion metric tons. In Madrid in December, the United Nations climate negotiations ended once again in failure. If current trends continue, the world in 2070 will be a very different and much more dangerous place—one in which flooding, drought, fire, and probably also climate-related unrest will have forced millions of people from their homes.

LAST YEAR I wrote an obituary for a snail named George. George was about an inch long, with a gray body and a shell ringed in beige and brown. He'd spent his entire 14-year life quietly slithering around a terrarium in Honolulu. Researchers with Hawaii's Division of Forestry and Wildlife had tried to find him a mate—George was a hermaphrodite but needed a partner to reproduce—and when they failed, they concluded he was probably the last of his kind, *Achatinella apexfulva*. A few days after George's death, the division posted a eulogy under the heading "Farewell to a Beloved Snail ... and a Species."

Achatinella apexfulva joined a long list of extinctions since 1970. Others include the Colombian grebe, the Yunnan lake newt, the golden toad, the Southern gastric brooding frog, and the Saudi gazelle. Several hundred more species, such as the Yangtze River dolphin, are listed as "possibly extinct" by the International Union for Conservation of Nature. Most of them have not been seen for decades. The list covers only the species the IUCN has assessed—probably less than 2 percent of what's out there. Extinction rates today are hundreds—for some groups, probably thousands—of times higher than they've been throughout most of geologic history.

And for every species teetering on the edge of oblivion, many more seem headed in that direction. According to the WWF's *Living Planet Report,* the wild populations of mammals, birds, fish, reptiles, and amphibians have shrunk, on average, by 60 percent since the first Earth Day. (This doesn't mean the total number of individual animals has dropped by 60 percent, because losses to small populations have a disproportionate impact on the figures; still, it's a pretty grim statistic.)

A study published last fall found that there are now some three billion fewer birds in North America than there were 50 years ago, a decline of nearly 30 percent, and that some of the steepest drops have been among such common species as blackbirds and sparrows.

"It's staggering," said Ken Rosenberg, a conservation scientist at Cornell Lab of Ornithology and the lead author of the study. Insects too appear to be dwindling. A study by European researchers published in 2017 found that the biomass of flying insects in a set of German protected areas had dropped by an alarming 76 percent just in the previous three decades.

Can we save a species in a lab?

Barbara Durrant extracts cell samples from cold storage at the San Diego Zoo Institute for Conservation Research. The Frozen Zoo houses 10,000 living cell lines of more than 1,100 species and subspecies. Researchers hope to convert stored cells into stem cells, which could then be used to create sperm, eggs, and perhaps embryos for use in saving endangered species. While conserving habitats and preventing poaching and hunting are still the best ways to save species, laboratory science may be the only hope for some.

BRENT STIRTON

If people are doing better than they were in 1970, clearly the opposite is true for most other creatures. The two trends can be traced to the same source. To feed, house, and provide energy for our own growing population, we've appropriated ever more of the world's resources for ourselves. People have significantly altered something like three-quarters of the ice-free land on Earth. More than 85 percent of the world's wetland area has been lost. All around the globe, farming has become more intensive, with more acres of monoculture and fewer of the weedy patches that used to provide sustenance for native insects, which in turn provide sustenance for birds. Even in places like national parks, suitable habitat for many species is shrinking because of factors such as climate change and invasive species.

"Wild creatures, like men, must have a place to live," the late American conservationist Rachel Carson observed.

The great question for the next 50 years is whether the trends of the past 50 years will continue. People could collectively decide to reduce their impact on other species by, for example, putting an end to deforestation and reconnecting fragmented habitats. But, as with cutting carbon emissions, there's no evidence that this is going to happen. On the contrary, tropical deforestation rates over the past few years have surged.

THE BIG BOOM IN RENEWABLE ENERGY HAS NOT REDUCED OUR USE OF FOSSIL FUELS, BECAUSE WE KEEP DEMANDING MORE AND MORE ENERGY.

A report last year by the international body charged with monitoring ecosystems and biodiversity warned that humanity could not continue to thrive while so many other creatures suffered. "Nature is essential for human existence," it noted. About three-quarters of all food crops, for example, rely on pollinators—birds, bats, or in the vast majority of cases, insects. Humans can't easily live without those animals.

"The essential, interconnected web of life on Earth is getting smaller and increasingly frayed," said ecologist Josef Settele of Germany's Helmholtz Centre for Environmental Research, and a cochair of the report.

Of course, Settele and his colleagues may be wrong, and for the same reason Downs was. Perhaps people will perfect pollen-carrying drones. (They're already being tested.) Perhaps we'll also figure out ways to deal with rising sea levels and fiercer storms and deeper droughts. Perhaps new, genetically engineered crops will allow us to continue to feed a growing population even as the world warms. Perhaps we'll find "the interconnected web of life" isn't essential to human existence after all.

To some, this may seem like a happy outcome. To my mind, it's an even scarier possibility. It would mean we could continue indefinitely along on our current path—altering the atmosphere, draining wetlands, emptying the oceans, and clearing the skies of life. Having freed ourselves from nature, we would find ourselves more and more alone, except perhaps for our insect drones. ▯

Elizabeth Kolbert is a staff writer for the *New Yorker* and a frequent contributor to *National Geographic* magazine; she wrote about human genetics in the April 2018 issue on race. She is the author of *Field Notes From a Catastrophe,* a book about climate change, and *The Sixth Extinction,* which won the Pulitzer Prize for nonfiction in 2015.

CLIMATE VS. CRAVINGS

EVERYTHING ABOUT THE WORLD'S FAVORITE FOODS—FROM HOW THEY'RE GROWN TO WHEN WE EAT THEM—COULD BE SUBJECT TO CHANGE IN A WARMER WORLD.

BY DANIEL STONE

1. COFFEE
Almost three-quarters of coffee comes from small farms. Warmer weather and plant diseases may drive up the price.

2. AVOCADOS
This fruit's trees don't like high heat. If growers shift to kinder environs, it could lengthen shipping distances.

3. SHRIMP
Ocean acidification affects crustaceans' health—and taste. Future shrimp may be less palatable, one study says.

4. SALMON
Warming water threatens this and other cold water fish. Less wild breeding may spur more farming to maintain supply.

5. WINE
The beverage will endure, but changes in terroirs will force vintners to find ways to maintain wines' signature tastes.

6. OLIVES
Early frosts, heavy rain, and wind halved Italy's production last year. Such extremes could limit crops in many places.

7. BANANAS
So far, warming has expanded the tropical fruit's growing area—and raised the risk of fungi that devastate plants.

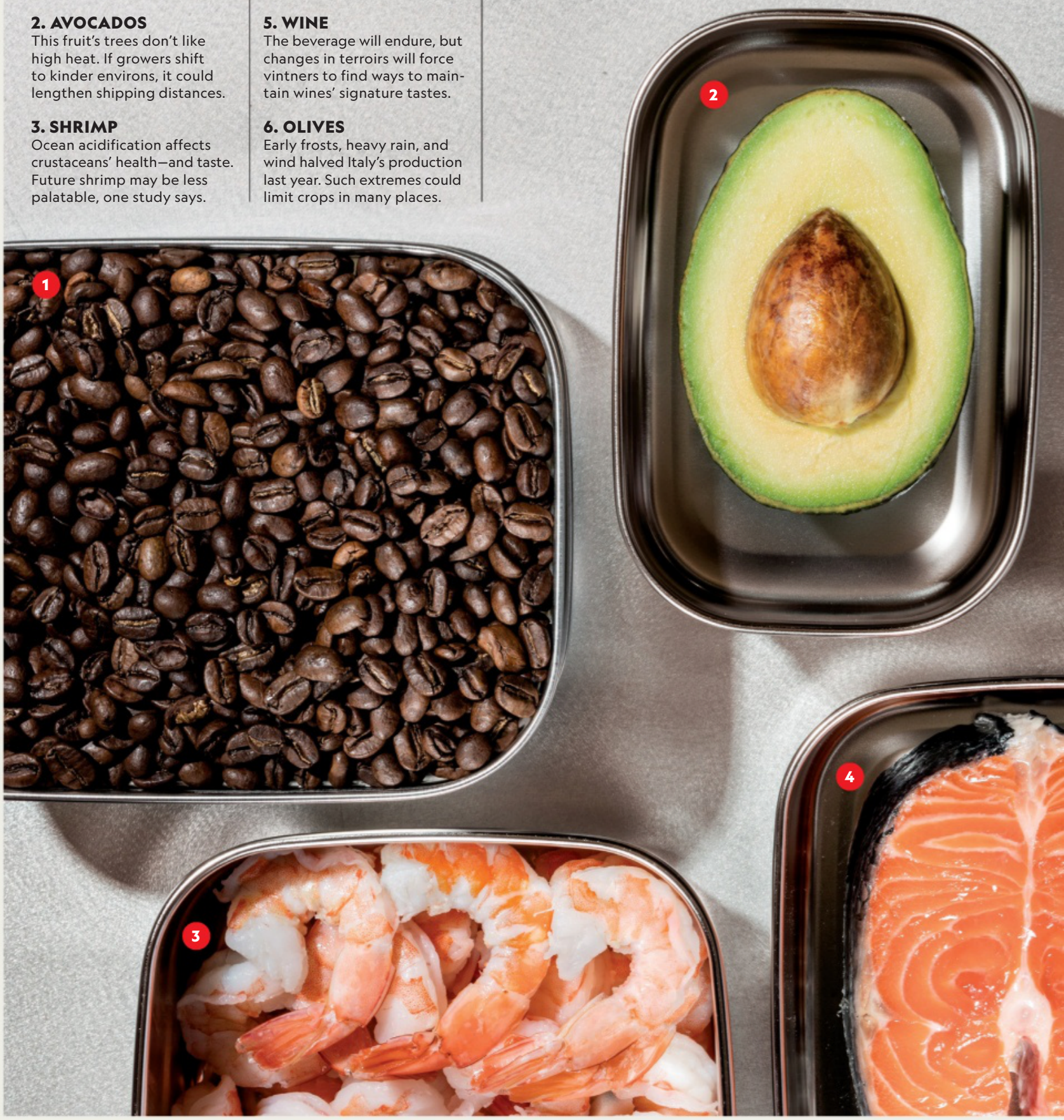


PHOTO: REBECCA HALE, NGM STAFF

EVEN IN THE BEST growing conditions—with moderate weather, predictable rainfall, and rounded seasons—growing food is hard. Add in climate volatility, erratic floods, and frequent drought, and the entire food system becomes an equation of anxiety, hope, and in some regions, dread. "We have a climate change threat to our food system and not many strategies to deal with it," says Michael Puma of Columbia University's Earth Institute.

What will that mean for our plates? Global commodities such as corn and wheat are susceptible to dramatic shifts in growing regions and crop output. The UN says that without strategies for adapting, lower staple yields will lead to shortages and increased prices for human and livestock consumption, hitting developing tropical countries the hardest. More charismatic foods, like the ones shown here, will morph in appearance, nutritional value, availability, and price as growing regions shift and farmers turn to warm-weather crops. Longer growing seasons are generally good news for farmers and plants, but lack of rainfall or insufficient cold weather could stunt even the best-laid seeds and plans.

Innovation will be part of foods' evolution, in the field and in the lab. Seed breeding and gene editing are helping some fruits and vegetables grow faster and bigger to outrun a season's heightened probability of flood or drought. Other technologies help food last longer to be shipped farther, in some cases not requiring refrigeration at all.

The UN's Intergovernmental Panel on Climate Change projects that the planet won't lose much arable land before 2050 and that few foods will disappear completely—but over the coming decades, crops and diets will evolve. Retaining the world's favorite foods and making them accessible to more people will require eating smarter, says Charlotte Streck, director of Dutch-based think tank Climate Focus. That means less meat, more plants, and getting all you can from as close as possible. □

DISPATCHES
FROM THE FRONT LINES
OF SCIENCE
AND TECHNOLOGY

Crabs release carbon

Salt marshes store millions of tons of carbon, but burrowing fiddler crabs may be letting it out. Their tunnels create holes in soil that expose carbon-releasing organic matter in Brazil, Tanzania, and China. Researchers say other burrowing animals, like clams and shrimp, may be doing similar damage. –DANIEL STONE

SEA RISE

HISTORIC FLOODING IN VENICE

TOURISTS WERE THE FIRST WAVE TO HIT THE CITY. THE SEA MAY BE THE LAST—AND MOST DESTRUCTIVE.

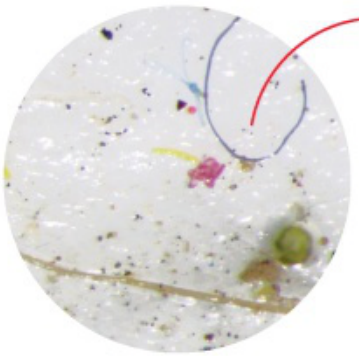
EVERY YEAR, AND after almost every rain, the headline is familiar. Venice is flooding and sinking at the same time, which leads to the same wet result: more water filling the 1,200-year-old city's streets at greater frequency for longer periods. Venice mayor Luigi Brugnaro says the city "will shine again"—but can the island possibly survive a warming world?

The sea level in Venice's lagoon is four inches higher than it was 50 years ago. The UN's Intergovernmental Panel on Climate Change expects that so-called hundred-year floods will occur every six years by 2050—and every five months by 2100. One such flood last November left 70 percent of the city submerged.

The more urgent priority may be saving Venice's treasures and artifacts. After November's flood, art experts and university students visited damaged museums and churches to move precious objects to higher floors. In some cases, they aimed to find the objects new homes outside of Venice.

That's only a stopgap until relief arrives from the Italian government's long-awaited MOSE defense project (also known as the Moses project), which will use giant seawalls to seal off the lagoon. Scheduled for completion in 2011, the project has been delayed by cost overruns and disputes. Officials now expect Moses to start protecting Venice by 2022. –DS

PHOTOS (CLOCKWISE FROM TOP LEFT): JOEL SARTORE, NATIONAL GEOGRAPHIC PHOTO ARK; DUNCAN CLARK, NORTHWEST PASSAGE PROJECT, FUNDED BY THE NATIONAL SCIENCE FOUNDATION AND THE HEISING-SIMONS FOUNDATION; JEFF DAI (PANORAMA COMPOSED OF FOUR IMAGES); GIUSEPPE CACACE, AFP VIA GETTY IMAGES; MIGUEL MEDINA, AFP VIA GETTY IMAGES



More than

10,000

microplastic particles per liter of Arctic sea ice

Plastics have colonized even Earth's pristine environments. Researchers found that polar waters and ice have the highest concentrations of ocean-based microplastics on the planet. Plastic waste is expected to quadruple in the next 30 years. –DS

GLOBAL WARMING

ALLERGIES ARE ON THE RISE

If you don't have springtime allergies, you might soon. And if you already do, they might get worse. The 2018 U.S. National Climate Assessment cautions that allergic illnesses like asthma and hay fever are likely to afflict more people amid climate change. Warmer temperatures and earlier springs combine to spur plants to release more pollen over a longer season to irritate your nose, throat, and eyes. –DS

Flowers produce pollen, but so do trees, grass, and weeds. Because pollen is fine, it's easily picked up by wind and lodged in nasal passages.

ARTIFICIAL LIGHTS

OUR NIGHTS ARE GETTING BRIGHTER

DARK SKIES ARE INCREASINGLY RARE, AND THAT COMES WITH HIDDEN COSTS.

LIGHT POLLUTION is now among the most chronic environmental perturbations on Earth. In 2016 scientists estimated that 99 percent of the continental United States and Europe suffer some amount of light pollution.

Their study found that a third of humankind—including nearly 80 percent of North Americans—cannot see the Milky Way. And data from the Suomi NPP satellite suggest that worldwide, light pollution increased by roughly 2 percent a year from 2012 to 2016.

All lights, but especially LEDs, are to blame. Because they're much more energy-efficient than incandescent and CFL bulbs, LED lights are left on for longer periods, casting cheap light in all directions.

Lack of darkness can affect any animal whose biology depends on circadian rhythms—including us, says Amanda Gormley of the International Dark Sky Association. "We lose a part of ourselves when we lose access to the night sky." **–NADIA DRAKE**

CHANGES WE DON'T SEE

A PHOTOGRAPHER DOCUMENTS HOW HUMANS HAVE RESHAPED THE EARTH, EVEN IN PLACES FAR BELOW ITS SURFACE.

STORY AND PHOTOGRAPH BY EDWARD BURTYNSKY

I CAPTURED THIS IMAGE in the potash mines below Berezniki, a Russian town in central Siberia. Most people don't have the visual or verbal vocabulary to really understand what's happening beneath the ground in that remote place. And until I visited it myself and felt the pressure of more than a thousand feet of solid earth and rock and life above me, neither did I.

This is a landscape that was never meant for human eyes. The light of the sun will never reach it. And yet the materials extracted here—destined to fertilize immense farms in the United States and elsewhere—are an essential ingredient in the production of food that sustains the world's booming population.

To arrive at this place—a 6,000-mile network of tunnels in utter uninhabitable darkness—my crew and I descended in an elevator large enough for some 40 miners and their equipment. It was foggy; the damp air would soon chill us to the bone. At the bottom of the shaft, we boarded trucks, the only illumination coming from the vehicles' headlights and our headlamps. Although I'd worked in a gold mine before I became a photographer, this experience was unsettling. The tunnels would split and split again and then split yet again. I began marking our path with an X. If our lights burned out, we would be lost and no one would hear our calls. Voices fade away quickly underground.

And yet it was beautiful down there amid the brightly colored layers of an ancient seabed—the orange striations of the potash, the undulating lines created by the intense pressure of the earth above. The nautilus-shell impressions, however, were made by a machine. The miners call it a combine; it excavates tunnels with spinning discs on two arms. When the combine reverses course, it carves these medallions into the rock.

Those impressions, and the tunnels themselves, are markers of the Anthropocene, a possible new geologic age defined by human activity. Scientists call such alteration to Earth's rock and sediment "anthroturbation." Long after our cities have been overgrown by forests, these tunnels will remain as clues to our existence, much as the cave paintings of Lascaux tell us of people who lived 20,000 years ago.

I've spent the past 40 years photographing the ways in which humans have altered natural landscapes, mostly through large-scale systems such as transportation, industry, and agriculture. I look for massive examples of what I call "human taking"—the removal from the Earth of the materials used to make our stuff. I'd be lying if I said I wasn't deeply concerned about this world of consumption that my daughters are inheriting.

Few people see where the resources that make their life possible come from. Most of us see skyscrapers but don't see the silica mines that created the glass. We see concrete but not the sandpits where it's made. We see farmland but not the forests that used to grow there—or the potash mines that provide the fertilizer that nourishes the crops. We don't see the yin to the yang—that for every one of our great creations, there is a greater act of destruction somewhere in nature. ▯

Edward Burtynsky's most recent work is the multimedia Anthropocene Project. His previous story for the magazine was about California's water crisis.

THEIR FUTURE CAN BE YOUR LEGACY

For many of us, creating or updating our will is one of those tasks that always seems to fall to the bottom of the pile. In fact, the average person takes more time to plan their vacation than to plan for their future. You owe it to yourself and your family to be prepared. When you leave a gift to the National Geographic Society in your will or trust, or by beneficiary designation, you can protect critical animal species for generations to come.

NATIONAL GEOGRAPHIC

PHOTO: FRANS LANTING

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African elephants at waterhole, Botswana

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THESE ANIMALS ARE SLIPPING AWAY

PHOTOGRAPHS BY JOEL SARTORE

PANDAS AND TIGERS may be the poster creatures for conservation, but thousands more threatened animals languish out of the spotlight. Most of them aren't cuddly or charismatic, but they're no less crucial to ecosystems. Of the 30,000 species documented as being at risk of extinction, 28 percent are reptiles—including six of the seven kinds of sea turtles. Birds are declining because of climate change, habitat loss, predation, and pesticides, with a whopping 2.9 billion fewer in North America than in 1970. Reversing the trend over the next half century requires focusing a lot more attention on these underappreciated rarities. —CHRISTINE DELL'AMORE

△ **CRITICALLY ENDANGERED**

Hawksbill turtle
Found in tropical and subtropical waters worldwide, hawksbill turtles are hunted for their eggs, meat, and beautiful shells, which are made into decorative tortoiseshell items. Fewer than 25,000 nesting females likely remain. Some conservationists have placed GPS tags on the 150-pound reptiles to gain insight into their mysterious underwater lives. The hawksbill above was photographed at the Australia Zoo Wildlife Hospital.

▽ **VULNERABLE**

Koala
Widespread hunting in the 19th and 20th centuries took a toll on koala populations. Now the fuzzy marsupials, often mistakenly called koala bears, face new perils: climate change; highways that fragment habitats; and the sexually transmitted disease chlamydia, which has ravaged some groups with a 100 percent infection rate. Wildfires have become a particular threat. Koalas rarely descend from the eucalyptus trees whose leaves make up the bulk of their diet, so many have been unable to escape the unprecedented fires in eastern Australia. These young koalas, or joeys, snuggle together at the Australia Zoo in Beerwah, Queensland.

◁ **ENDANGERED**

Gray crowned crane
The population of this endangered African crane has dropped from more than 100,000 wild individuals to some 30,000 in the past 35 years. Reaching heights of around three feet, the elegant bird has suffered from poaching for its meat and eggs, as well as from the destruction of the wetland habitat where it breeds and hunts. The crane pictured here is a captive animal at France's Parc des Oiseaux.

NATIONAL GEOGRAPHIC PHOTO ARK

EARTH DAY 2070

PAGE 30

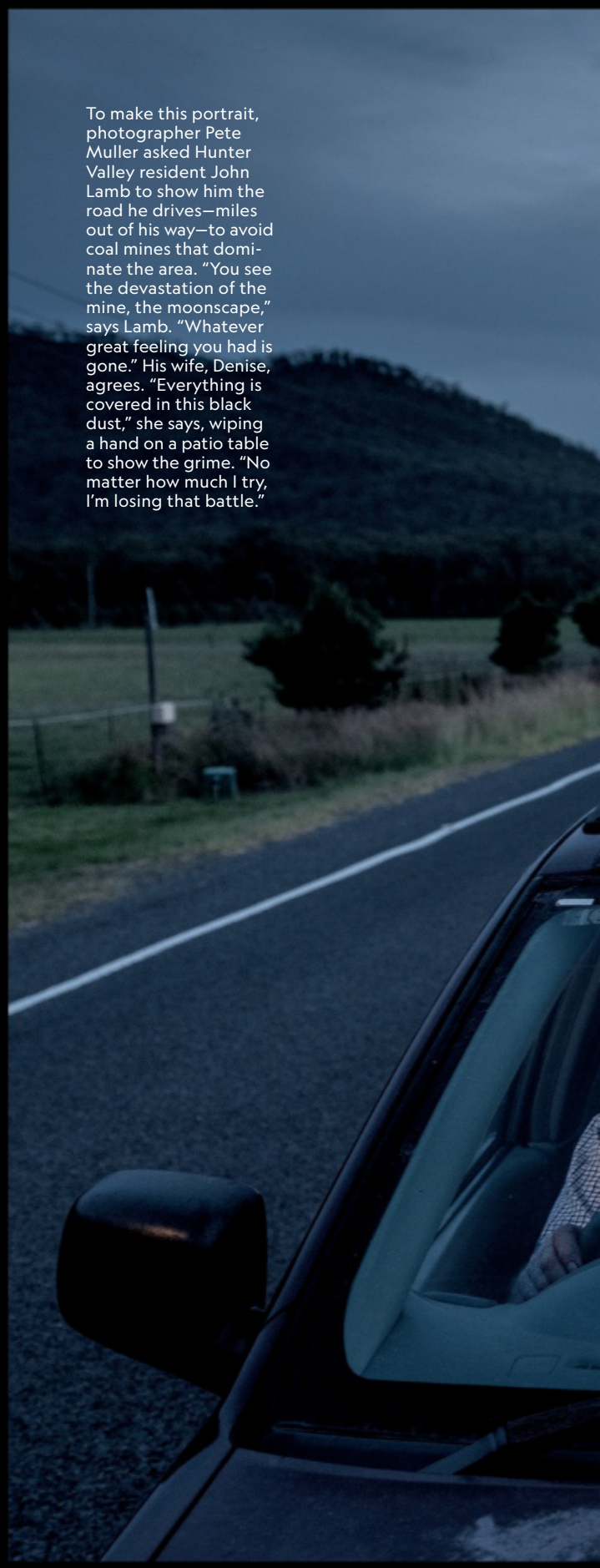
A WORLD LOST

STORY AND PHOTOGRAPHS BY PETE MULLER

AS THE PLACES WE'VE LOVED CHANGE, THE EMOTIONAL TOLL ON US IS 'SOMETHING AKIN TO HOMESICKNESS.'

A STRETCH OF THE CHUKCHI SEA, BETWEEN SIBERIA AND ALASKA, IN SUMMER. THE AVERAGE EXTENT OF THE SEA'S ICE IN 2019 WAS THE LOWEST SINCE SATELLITES BEGAN TRACKING IT IN 1978. WITHOUT ICE, COASTAL VILLAGERS CAN'T HUNT MANY OF THE ANIMALS THEY'VE RELIED ON FOR GENERATIONS.

The Mount Thorley Warkworth coal mine is one of several "super pit clusters" in Australia's Hunter Valley. It operates 365 days a year and provides jobs for some 1,300 people. The owner is currently considering plans to expand. But many residents say the massive mine has created a sense of sorrow among them. "It's not just grieving for what has been," says one resident. "It's also grieving for what could be and will now not be."



To make this portrait, photographer Pete Muller asked Hunter Valley resident John Lamb to show him the road he drives—miles out of his way—to avoid coal mines that dominate the area. "You see the devastation of the mine, the moonscape," says Lamb. "Whatever great feeling you had is gone." His wife, Denise, agrees. "Everything is covered in this black dust," she says, wiping a hand on a patio table to show the grime. "No matter how much I try, I'm losing that battle."

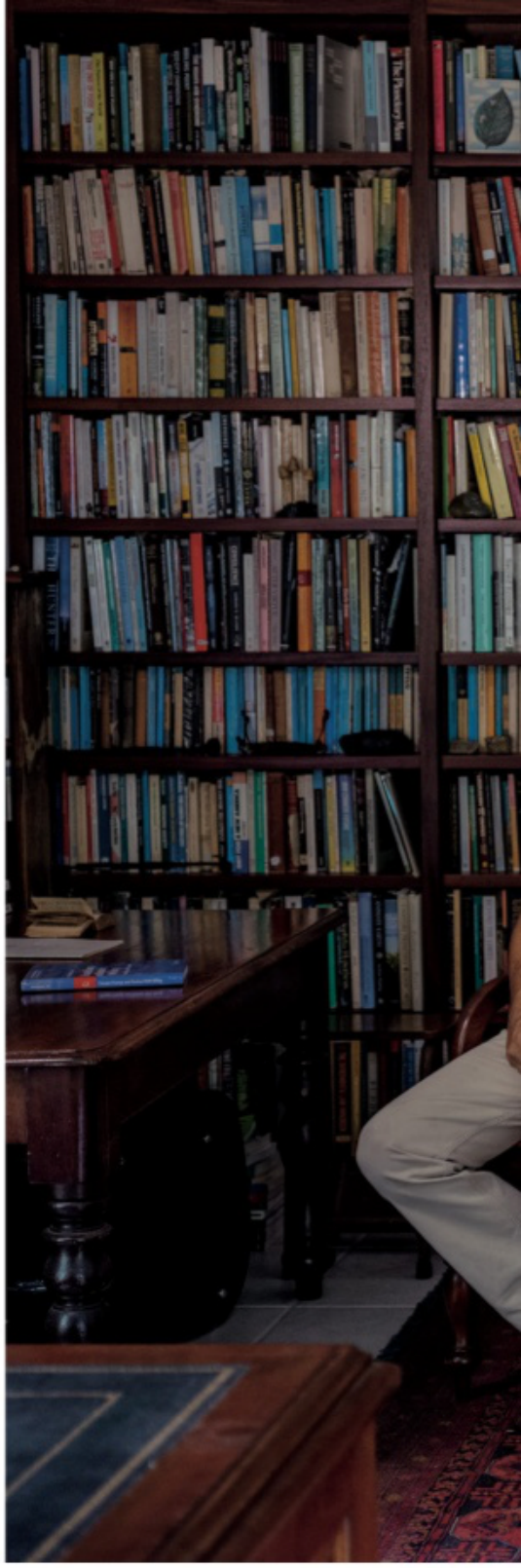
AS COAL MINES SPREAD LIKE CRACKS

across Australia's Hunter Valley, the phone in Glenn Albrecht's office began to ring. It was the early 2000s, and Albrecht, an environmental studies professor, was interested in the emotional impacts of mining on local communities. For generations, the region had been known for its bucolic alfalfa fields, horse farms, and vineyards. Coal mining had long been a part of the economy, but it had suddenly grown as increasing global demand and new extraction technologies prompted a wave of new mining operations across the valley.

Word of Albrecht's interest spread, and distressed residents were eager to share their stories. They described earth-shaking explosions, the constant rumble of machinery, the eerie glow of industrial work lights that illuminated the night, and invasive black dust that coated their houses inside and out. They worried about the air they breathed and the water they drank. Their homes were slipping away, and they felt powerless to stop the destruction.

Some in the valley mounted a legal battle to try to keep the mines at bay, but many needed the jobs the mines provided. Ultimately, the deep-pocketed mining interests prevailed. The landscape, and much of the social fabric built upon it, became collateral damage.

As the mines spread, Albrecht began to notice a common theme in the emotional responses of some valley inhabitants. They knew the mines were the source of their distress, but they had a difficult time finding the precise words to express their feelings. "It was as though they were experiencing



Glenn Albrecht and his wife, Jill, sit for a photo in their Hunter Valley home. Glenn coined the term "solastalgia" in the early 2000s to describe residents' emotional turmoil as coal mining exploded in the region. The word spread via the internet as a way to describe losing something beloved because of environmental change.

something akin to homesickness," he says, "but none of them had left home."

What was happening, he reasoned, was that the physical degradation of the valley was undermining the solace that people had felt there. And so, as the mines churned more green fields to gray, Albrecht named the feeling the residents were describing "solastalgia," which he defined as the pain of losing the solace of home.

More than a decade later, I heard this unusual word while watching a film about drought. I made a note, unsure of how to spell it. Thanks to Google's did-you-mean feature, I discovered tens of thousands of related hits. There were academic articles, conferences, and news stories. The concept also had seeped into the art world. I found a sculpture exhibition in New Jersey, a pop album in Australia, a classical concerto in Estonia, all inspired by Albrecht's word.

While I was scanning the pages of Google hits, it occurred to me that the concept of solastalgia seemed to mark a new frontier in our relationship with the environment, an acknowledgment of a strange brew of emotions that more people were feeling as familiar landscapes became unrecognizable. We all know that humans are changing the planet, but here, in this new word, was a trace of how those changes are changing us.

"If the language is not rich enough to enable us to describe and understand these things properly, well, we bloody well have to create it," Albrecht told me when I visited his home in the Hunter Valley. "Why don't we have a single word," he asked, "that corresponds to a human feeling?" Especially a feeling "that is profound, obvious, felt worldwide in various contexts, and

has likely been felt for thousands of years in similar circumstances."

It seemed like a valid question. Throughout history, floods, wildfires, earthquakes, and volcanoes—as well as expanding civilizations and conquering armies—have permanently altered treasured landscapes and disrupted societies. Native Americans experienced this as Europeans transformed North America. "This land belonged to our fathers," Satanta, the 19th-century Kiowa leader, said. "But when I go up to the [Arkansas] river, I see camps of soldiers on its banks. These soldiers cut down my timber, they kill my buffalo; and when I see that, my heart feels like bursting."

The industrial revolution brought more sweeping changes to landscapes with the spread of burgeoning metropolises, railroads, and factories. As New York's Hudson Valley was cleared to make way for agriculture and feed a thriving tannery industry, the 19th-century painter Thomas Cole lamented the destruction of his beloved forests. "I cannot but express my sorrow that the beauty of such landscapes is quickly passing away," he wrote. "The ravages of the axe are daily increasing—the most noble scenes are made desolate, and oftentimes with a wantonness and barbarism scarcely credible in a civilized nation."

'I CANNOT BUT EXPRESS MY SORROW THAT THE BEAUTY OF SUCH LANDSCAPES IS QUICKLY PASSING AWAY.'
THOMAS COLE, HUDSON RIVER SCHOOL PAINTER

My mother experienced a less severe version of the feeling during the mid-20th century. She grew up on Long Beach Island, a narrow, isolated spit of sand off the coast of southern New Jersey. In its pristine marshes, she discovered her lifelong love of biology and the sea. But in the 1950s, real estate development accelerated as wealthy visitors from the mainland bought land and built vacation homes. "I could sense immediately what was happening," she says. "I was furious. I would go around pulling up the surveyors' sticks."

Her protests were motivated not simply by anger but also by a mixture of fear, powerlessness, anxiety, and sorrow that the defining character of her home was in peril. The construction continued, and within a few decades, the past was visible only in the osprey nests atop electrical poles that provided light in the homes that had replaced the wilderness.

Changes like these have always occurred. It is the nature of our dynamic species to reshape landscapes to meet our needs and desires, but the scale and pace of transformation in the 21st century are unprecedented. As our population rapidly approaches eight billion, humans are altering the planet more than at any other point in recorded history. We continue to raze forests, emit carbon, and flush chemicals and plastics into the land and water. As a result, we confront ruinous heat waves, wildfires, storm surges, melting glaciers, rising sea levels, and other forms of ecological destruction. All of this causes political, logistical, and financial disruption. It also creates often overlooked emotional challenges.

Only in recent years have scientists begun to devote significant resources to studying how altering the environment affects mental health. In the biggest empirical study to date, a team led by researchers from MIT and Harvard looked at the effects of changes in the climate on the mental health of nearly two million randomly selected U.S. residents from 2002 to 2012. Among other things, they found that exposure to heat and drought magnified the risk of suicide and raised the number of psychiatric hospital visits. In addition, victims of hurricanes and floods were more likely to suffer post-traumatic stress disorder and depression.

For those who endure the trauma of losing a landscape, the emotions can be wrenching to express. "The pain of losing a land is totally different than any other pain, because it is difficult to share," Chantel Comardelle tells me when I

In "The Oxbow" (above), 19th-century painter Thomas Cole depicted a Massachusetts river valley stripped of trees. In New York he would lament the loss of forests in the Hudson River Valley as farming spread there.

visit her community on the coast of Louisiana, where the sea is rising at an alarming rate and flooding the land. Comardelle was born on Isle de Jean Charles, a dwindling island that has lost 98 percent of its land since 1955. During her parents' generation, the island's mostly Native American inhabitants hunted and farmed. Now many families have left. The community has fractured. "It's not like losing a loved one or something that other people easily understand," she says.

But in the era of global climate change, more people do understand. As Isle de Jean Charles disintegrated, Comardelle and other local leaders decided to reach out to those facing similar challenges. "There's a community in Alaska that's going through the same thing," she says, referring to the Yupik village of Newtok, also confronting acute subsidence and land loss. "We were able to sit down and talk … and it was almost exactly the same feelings, the same emotions," she says. "It was like, OK, so I'm not alone. This isn't just something that I'm making up in my mind. It was real."

During the past few years I've traveled to several places—from the Arctic to the Andes—where the landscape has undergone a dramatic transformation. I wanted to better understand not only the physical changes to the land but also how those changes reverberate within the lives of their inhabitants. Only a handful of people I met had heard the word solastalgia, but a great many shared haunting descriptions of the experience the word aims to define. They grapple with both the daunting practical challenges of losing a landscape and the complex emotional strain of losing their sense of place in the world.

For now, solastalgia is buzzing at the edges of language—almost exclusively English—and Albrecht hopes it stays there. "It's a word that shouldn't exist but had to be created out of difficult circumstances," he says. "It's now become global. That's terrible … Let's get rid of it. Let's get rid of the circumstances, the forces, that create solastalgia." ▯

Photographer **Pete Muller**'s images of how boys become men around the world appeared in the January 2017 issue. This project was supported by a National Geographic Society Fellowship.

METROPOLITAN MUSEUM OF ART, NEW YORK/ART RESOURCE, NY

RIGHT

Stanislav Vykvytke harpoons a walrus south of the village of Lorino, Russia. In the past Chukchi hunters took dog-sleds across the sea ice, but now the ice is too thin. "That's why we started using boats in the wintertime," he says. Hunting is central to Chukchi identity. "Hunting is a dynasty," Eduard Ryphyrgin says. "Older men in the family teach the younger men in an uninterrupted chain."

BELOW

Inna Tynelina (at left) feeds her family whale meat and soup made from vegetables imported into the village. Marine mammals account for most of the diet of coastal Chukchi communities, where more than half of the people live solely on what can be harvested from the sea. "It is the meat that gives us the energy for our lives," says Teyu Nelia Vasilievna, a local cook. "The food in these shops is very expensive ... We cannot survive without our hunters."

65.50°N, 171.70°W

LORINO, RUSSIA

'WE CAN'T GROW VEGETABLES. WE CAN ONLY LIVE OFF WHAT THE SEA GIVES US. OUR ANCESTORS HAVE OBSERVED PERIODS OF WARMING AND COOLING. IT'S HARD FOR US TO KNOW WHAT IS REALLY HAPPENING.'

ALEXEY OTTOI, HUNTER

POLICE

Chukchi hunters butcher a gray whale on the shore near Lorino, Russia. The meat will be distributed to the community. Hunting has seen the Chukchi through many hard times, including the collapse of the Soviet Union when shops were bare. “Even [ethnic] Russians began to eat marine mammals,” says Eduard Ryphyrgin. But the quarry may soon be gone as the crucial edge of coastal ice that forms in winter diminishes because of climate change. “Animals that we eat need this edge,” Ryphyrgin says. “We need this edge.”

RIGHT

A mobile home community along the Honey Run Road in Paradise, California, was one of many neighborhoods destroyed by the so-called Camp fire in 2018. The state's deadliest, most destructive fire on record, it killed 86 people, displaced tens of thousands in the region, and burned almost all of Paradise (population 26,800).

BELOW

Muller made this portrait of Don Criswell playing the piano for his wife, Debbie, in their house, one of the few in Paradise to survive. Before the fire, Don performed up to five nights a week in Paradise. "It went to zero in one moment," he says. The Criswells are thankful their home didn't burn, but the Paradise they knew has disappeared. In their house, says Debbie, "we can sort of pretend everything is OK. But then you drive up the road and remember that the *place* where it was is gone."

39.75°N, 121.61°W

PARADISE, CALIFORNIA

'IF YOU GO LOOK AT A MAP, YOU'LL FIND PARADISE, CALIFORNIA 95969, BUT EVERYTHING ABOUT IT IS DIFFERENT … YOU FEEL LOST IN YOUR OWN TOWN. AND THAT'S A VERY DIFFICULT THING TO PROCESS.'

KAYLA COX, HOMEMAKER

Gwen Nordgren sits for a portrait by the pool next to the charred ruins of her former home in Paradise, California. Two months after the fire, Nordgren allowed Muller to accompany her on her return to say goodbye to the "perfect retirement house," a place filled with 15 years of memories. The pool holds a special place in her thoughts. "I would go in the pool in the morning by myself," Nordgren says. "I'd get into my bathing suit and get into this gorgeous pool, and I just felt like a queen. I'd look up at this beautiful California blue sky."

RIGHT

Men from Peru's Paruro nation pray before a glacier during the annual festival known as Qoyllur Riti, which means "snow star" in the Quechua language. Each spring hundreds of thousands of Peruvians come to these highlands in the Cusco Region to sing, dance, and pray as the Pleiades star cluster comes back into view.

BELOW

Norberto Vega, president of the festival, hugs a young man after a ceremony at the foot of a glacier. "Each year, when I see the glaciers getting farther and farther away, I feel like crying," he says. "We feel very helpless … We have taken specialists to the glacier to look for ways to maintain it or a way to control its disappearance. But we couldn't find a way out. I feel a lot of sadness because I know that over time I wasn't going to be able to keep practicing the rituals that are done in the sanctuary, on the ice."

13.54°S, 71.23°W

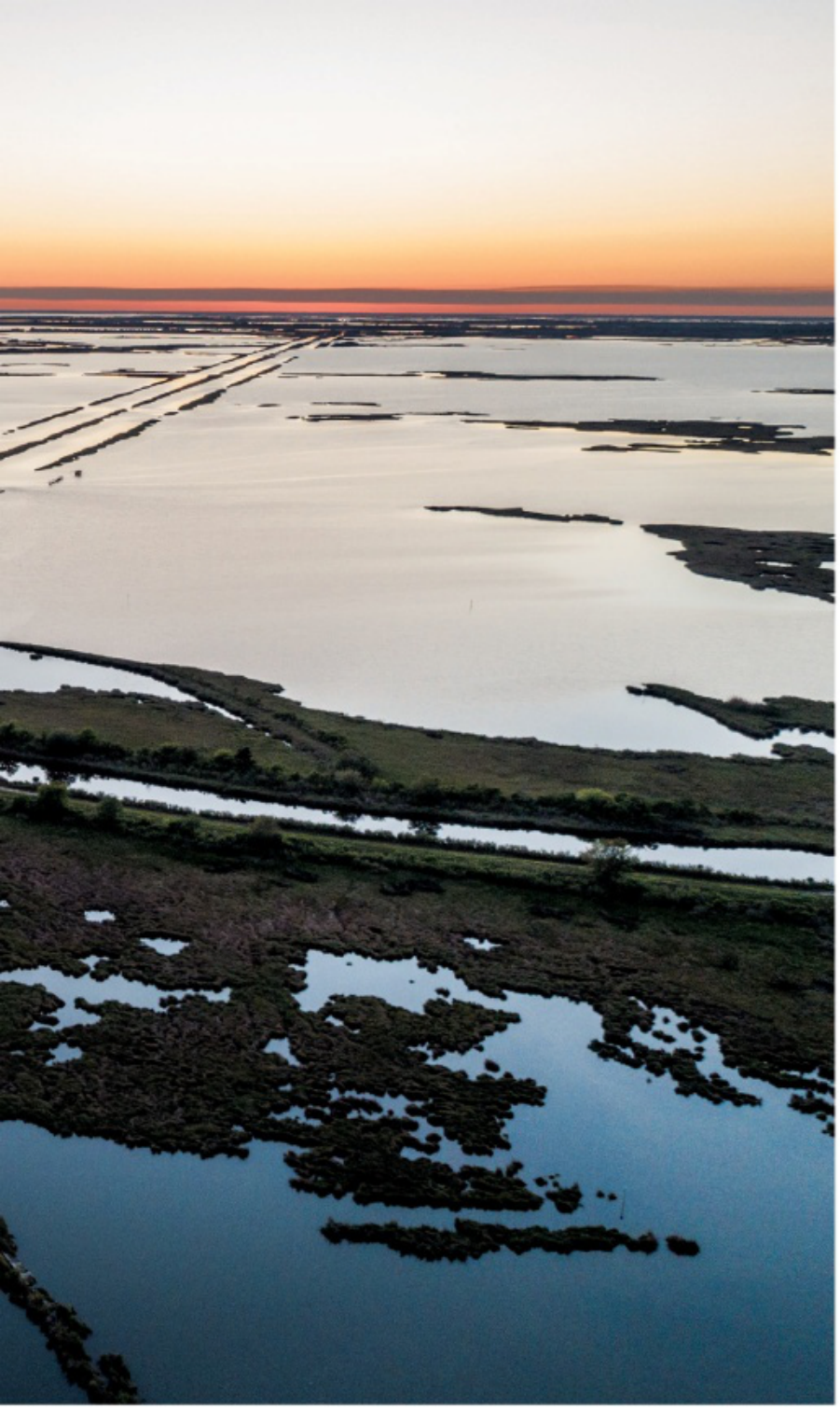
PAGE 50

COLQUE PUNKU GLACIER, PERU

'IT'S A REAL FEELING OF CONCERN BECAUSE WE ARE WATER, RIGHT? HUMAN BEINGS, WE ARE WATER. THEY TELL US THIS SINCE SCHOOL. THAT THE GLACIERS ARE FINISHING IS TELLING US THAT WE WILL ALSO FINISH IN SOME WAY.'

CLARK ASTO, QUISPICANCHI DANCER

Huddling around candles before dawn, men from Peru's Quispicanchi nation celebrate Qoyllur Riti below a glacier. Pilgrims believe the glaciers hold healing properties. But because the ice has receded so dramatically, cutting pieces of it is now banned. "We used the ice as medicine," says Norberto Vega. "Just by passing the ice over [your body] made you feel better, and that links with faith."



LEFT

Tides and storms often flood the only road that connects Isle de Jean Charles to the U.S. mainland, cutting off the 60 or so remaining inhabitants, most of whom are of Native American heritage. The island once covered 22,000 acres. Now it's 320. "You don't really know the land around you is disappearing … It was disappearing little bit by little bit, and now it's gone," says Albert Naquin, chief of the island's band of the Biloxi-Chitimacha-Choctaw tribe.

BELOW

Eight-year-old Bayah Bergeron picks berries by an abandoned house across the street from her home. Bayah's family is one of many considering leaving the island for a fresh start inland. But Bayah worries about her friend Avery, whose family is thinking about staying. "She might not move, and the rest of the people probably will, and that'll make me very sad for leaving my friend."

29.40°N, 90.49°W

ISLE DE JEAN CHARLES, LOUISIANA

'IT'S LIKE ALL THE TREES ARE DEAD NOW. I WANTED TO LIVE DOWN HERE, BUT AS I GROW OLDER, I REALIZE IT'S NOT POSSIBLE. MOTHER NATURE IS TAKING IT AT THIS POINT. IT'S A HURT TO YOUR SOUL. IT'S FEELING LIKE I LOST A LOVED ONE.'

VOSHON DARDAR, FISHERMAN

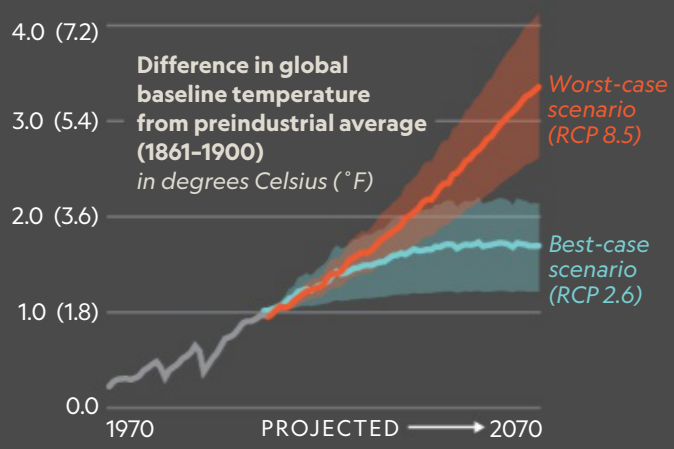
Chantel Comardelle and her family sit for a portrait in her grandparents' home on Isle de Jean Charles. Their ancestors arrived here in the 1820s, but now the rising Gulf of Mexico is swallowing the island. Chantel (seated at table) helps residents resettle on the mainland. Their feelings are difficult to explain, she says. "I can't just say, you know, 'the pain of losing a loved one.' This sort of losing a land and the things that are surrounded by the land is so different than that."

EARTH DAY 2070

THE WORLD IN 2070

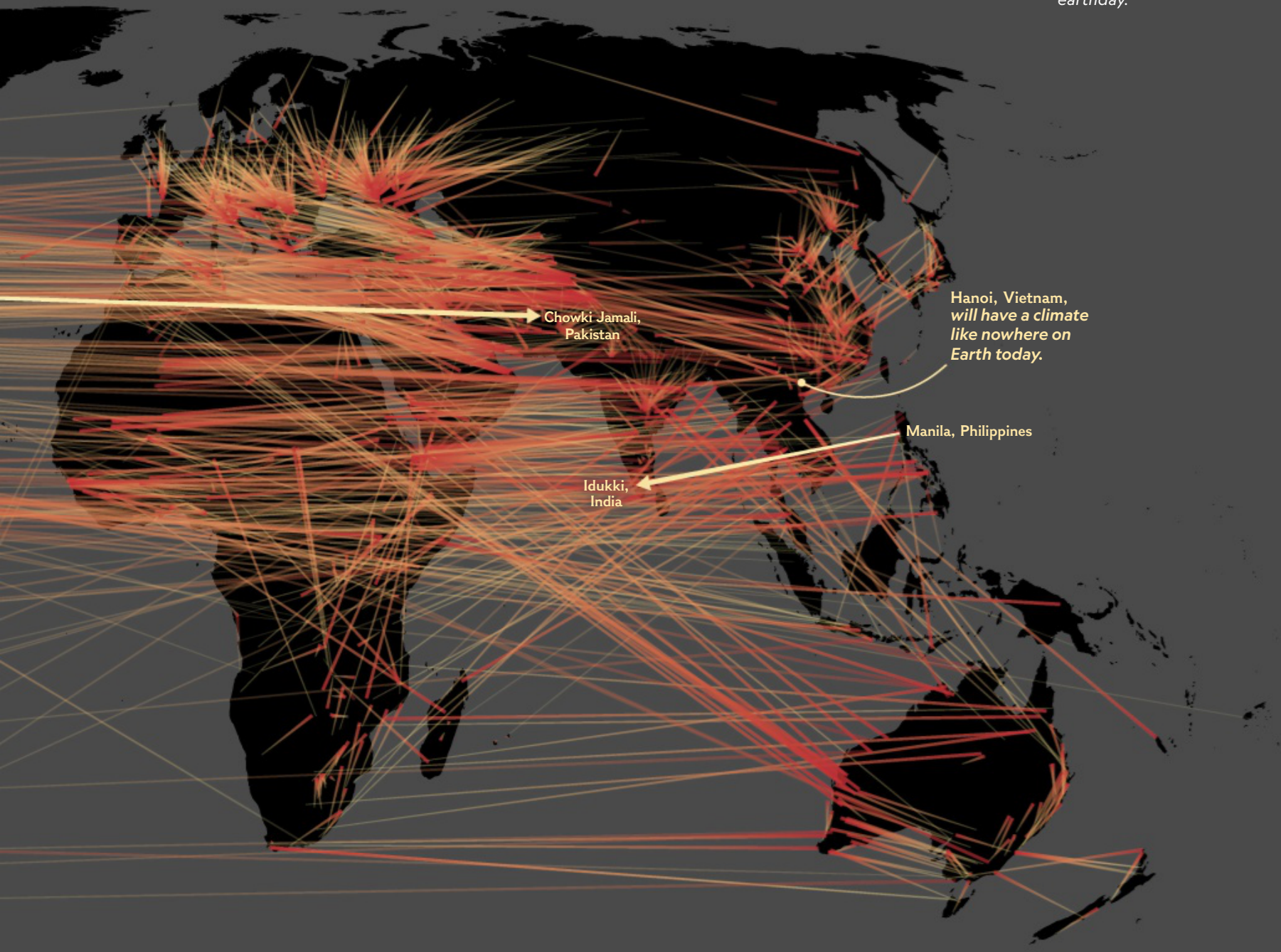
BY KAYA LEE BERNE, ALEJANDRA BORUNDA, RILEY D. CHAMPINE, AND JASON TREAT

IT'S NOT CLEAR WHETHER WE WILL REIN IN OUR CARBON EMISSIONS. IT'S MUCH CLEARER WHAT THE CLIMATE WILL BE LIKE IF WE DON'T: NOT GOOD.



The Intergovernmental Panel on Climate Change identifies future climate scenarios, called representative concentration pathways (RCPs), ranging from worst-case scenario, RCP 8.5, to best, RCP 2.6. Data here use RCP 8.5 unless otherwise noted.

Want to see what your city will be like in 2070? Visit *natgeo.com/earthday.*



TOMORROW'S CLIMATE, TODAY

Earth has warmed about one degree Celsius (1.8°F) since the industrial revolution. In a worst-case scenario in which our carbon emissions continue to rise, the warming could exceed three degrees Celsius (5.4°F) by 2070. That global average conceals dramatic local increases in extreme heat, precipitation, and drought. What climate might confront the world's cities in 2070? For some, it could be unlike any found on Earth today.

The nonprofit National Geographic Society, working to conserve Earth's resources, helped fund this project.

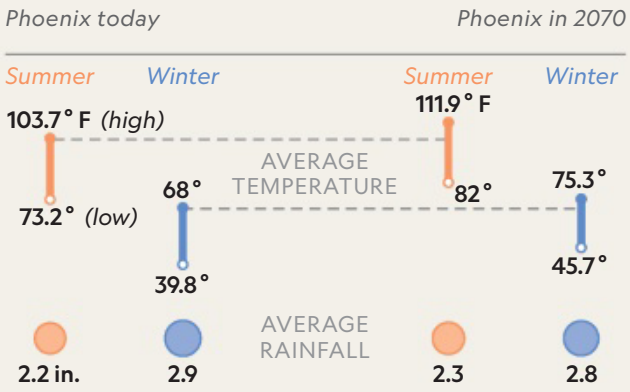
Location of city — **2070 climate analog**

This city in 2070 ▶ *will have a climate like this place today*

Sister cities of the future
The lines on this map, based on worst-case projections created by climate scientist Matt Fitzpatrick, connect cities today to their 2070 analogs—the places, if any, where their 2070 conditions exist already.

SOURCES: MATT FITZPATRICK; GEERT JAN VAN OLDENBORGH; KNMI CLIMATE EXPLORER

PHOENIX, UNITED STATES, WILL HAVE A CLIMATE LIKE TODAY'S BALOCHISTAN, PAKISTAN.



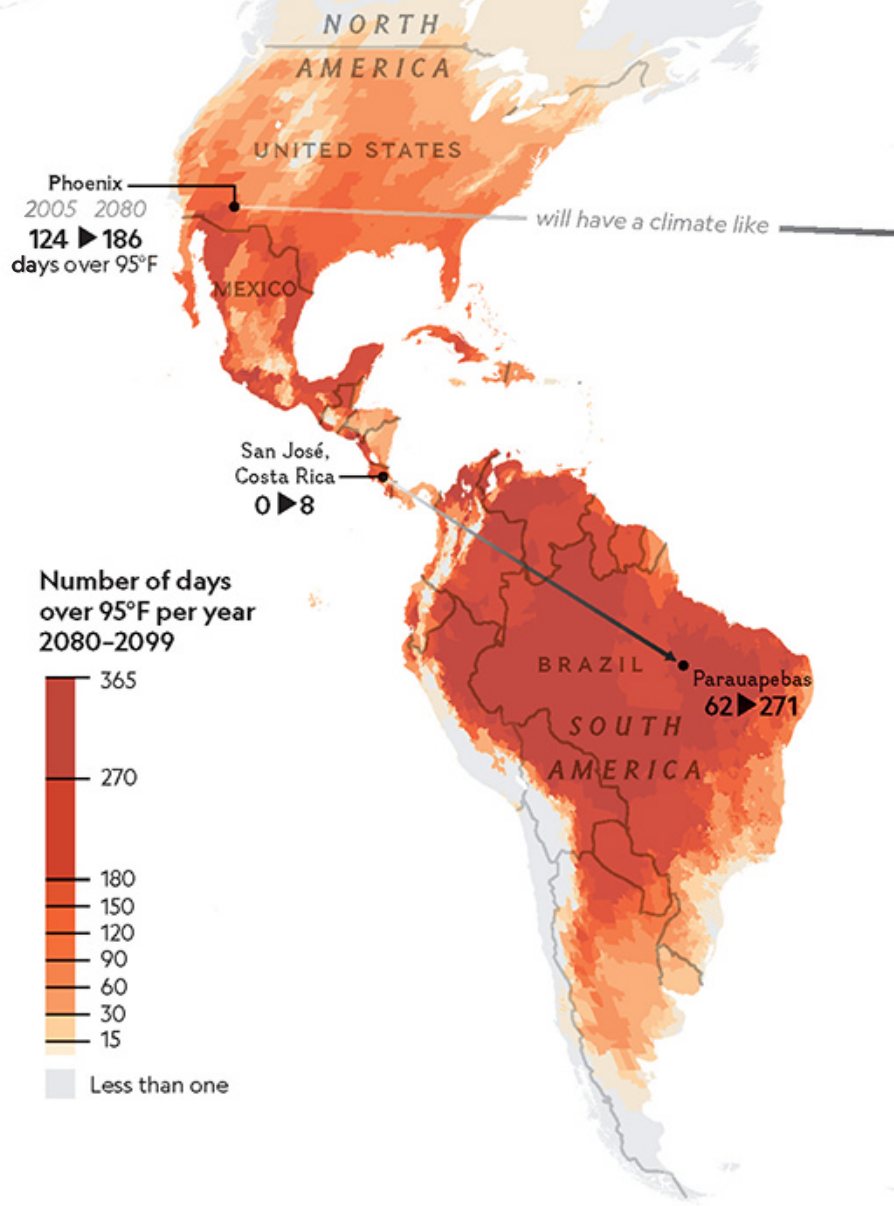
HEAT WILL GET DEADLY

By 2070, the climate in Phoenix, Arizona, already burning hot, will feel like today's Chowki Jamali in Pakistan's Balochistan Province, a high-desert region hit hard by drought and sky-high temperatures. Farmers there already schedule working hours for brief stretches of bearable temperatures in the early morning (which stand to shrink even further by 2070). Phoenix has shattered 34 daily heat records during the past decade; heat stress in the city hits low-income neighborhoods harder than wealthy ones, which often have more trees and cooling strategies to mitigate sweltering temperatures. By 2070 the annual number of days over 95°F in Phoenix is predicted to top 182—about half the year. But it's not just obviously hot places that will experience an increase in deadly heat: Today's temperate cities, where cooling infrastructure doesn't exist or is prohibitively expensive, will struggle mightily to keep their populations cool and safe.

This city in 2070		*will have a climate like*
SAN JOSÉ, COSTA RICA	▶	**PARAUAPEBAS, BRAZIL**
PARIS, FRANCE	▶	**MONTEFIASCONE, ITALY**
DAR ES SALAAM, TANZANIA	▶	**RAYONG, THAILAND**

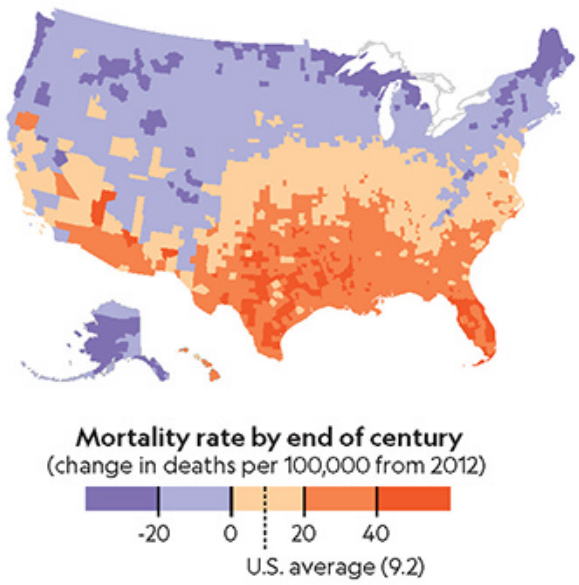
DANGEROUS DAYS

Since 1970, the global average temperature has increased 0.17°C (0.3°F) a decade, more than double the rate in all of the 20th century. Heat wave frequency and length will continue to rise, resulting in an unprecedented number of days when people have to take measures to stay cool.



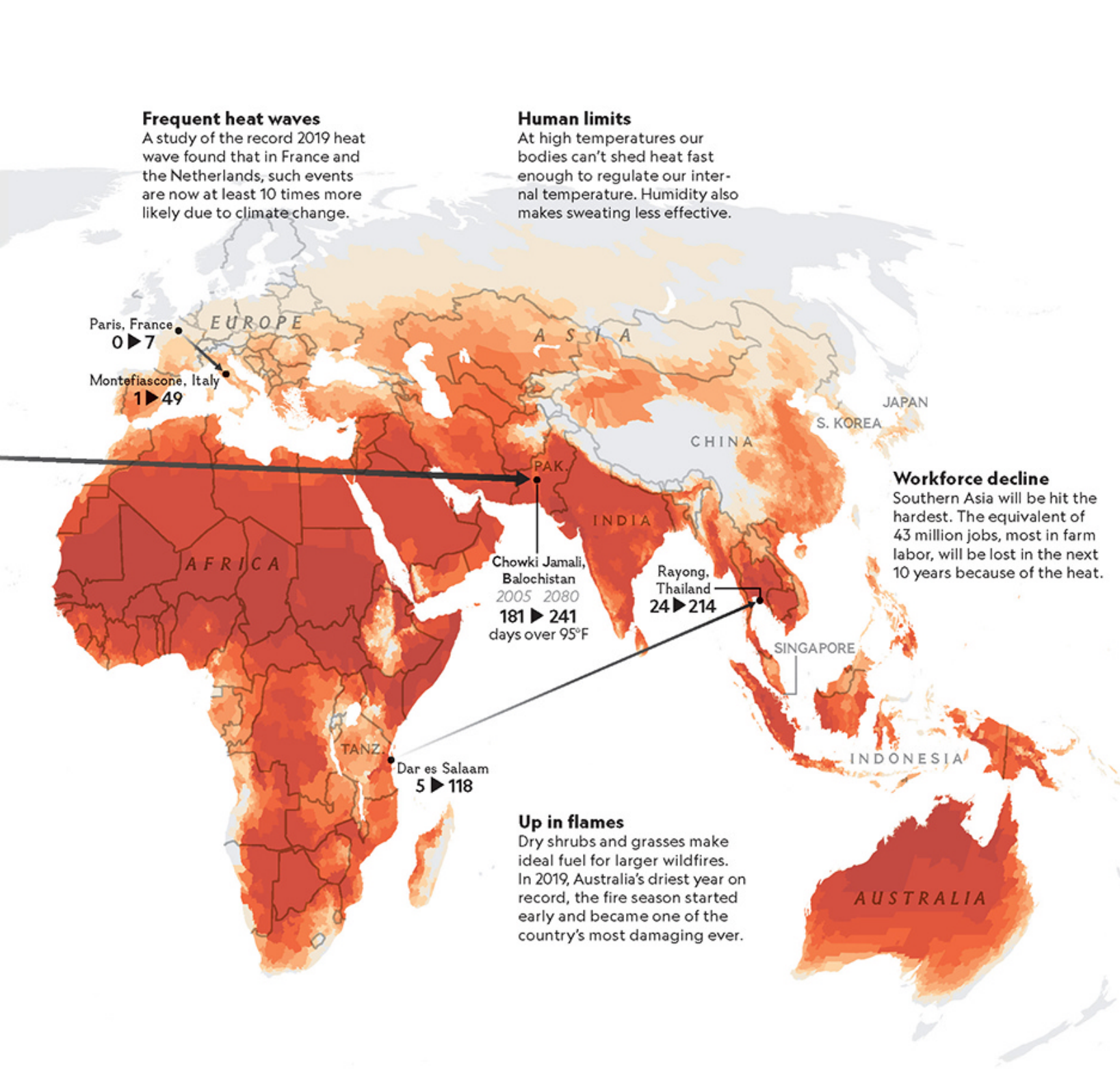
A TROUBLED SOUTH

Higher temperatures exacerbate health risks in the already hot parts of the U.S., such as the South and the Southwest, especially for low-income and vulnerable populations. Without new measures to shield them—or to cut emissions—mortality from all causes could rise dramatically.



Frequent heat waves
A study of the record 2019 heat wave found that in France and the Netherlands, such events are now at least 10 times more likely due to climate change.

Human limits
At high temperatures our bodies can't shed heat fast enough to regulate our internal temperature. Humidity also makes sweating less effective.



Workforce decline
Southern Asia will be hit the hardest. The equivalent of 43 million jobs, most in farm labor, will be lost in the next 10 years because of the heat.

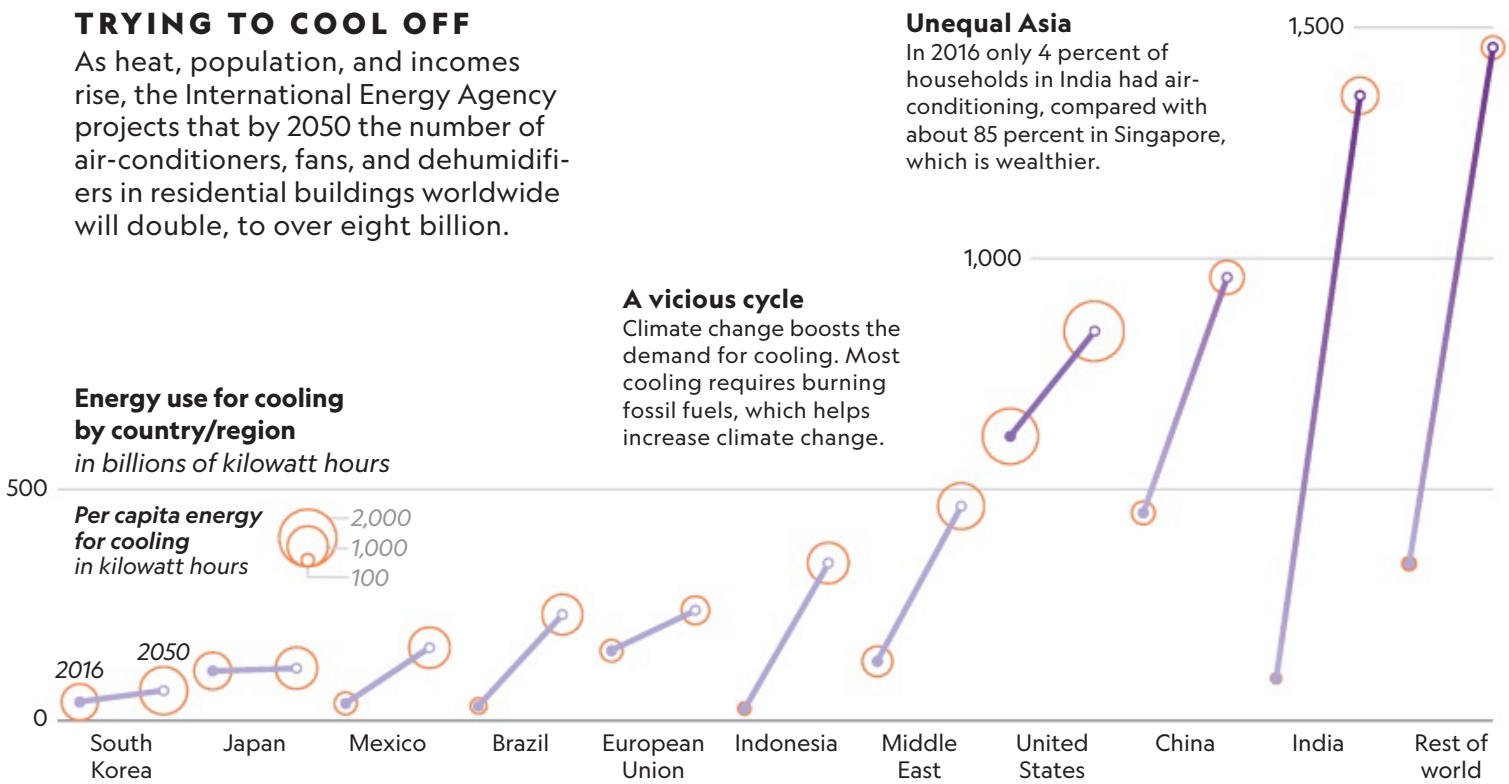
Up in flames
Dry shrubs and grasses make ideal fuel for larger wildfires. In 2019, Australia's driest year on record, the fire season started early and became one of the country's most damaging ever.

TRYING TO COOL OFF

As heat, population, and incomes rise, the International Energy Agency projects that by 2050 the number of air-conditioners, fans, and dehumidifiers in residential buildings worldwide will double, to over eight billion.

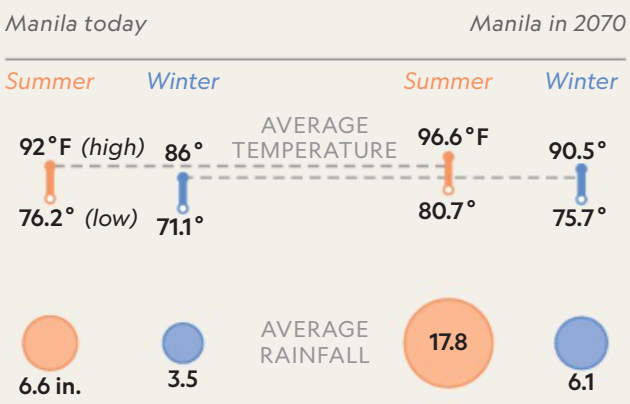
Unequal Asia
In 2016 only 4 percent of households in India had air-conditioning, compared with about 85 percent in Singapore, which is wealthier.

A vicious cycle
Climate change boosts the demand for cooling. Most cooling requires burning fossil fuels, which helps increase climate change.



CHRISTINA SHINTANI, NGM STAFF. SOURCES: CLIMATE IMPACT LAB; INTERNATIONAL ENERGY AGENCY; SOLOMON HSIANG AND OTHERS, *SCIENCE*, JUNE 30, 2017

MANILA, PHILIPPINES, WILL HAVE A CLIMATE LIKE TODAY'S KERALA, INDIA.



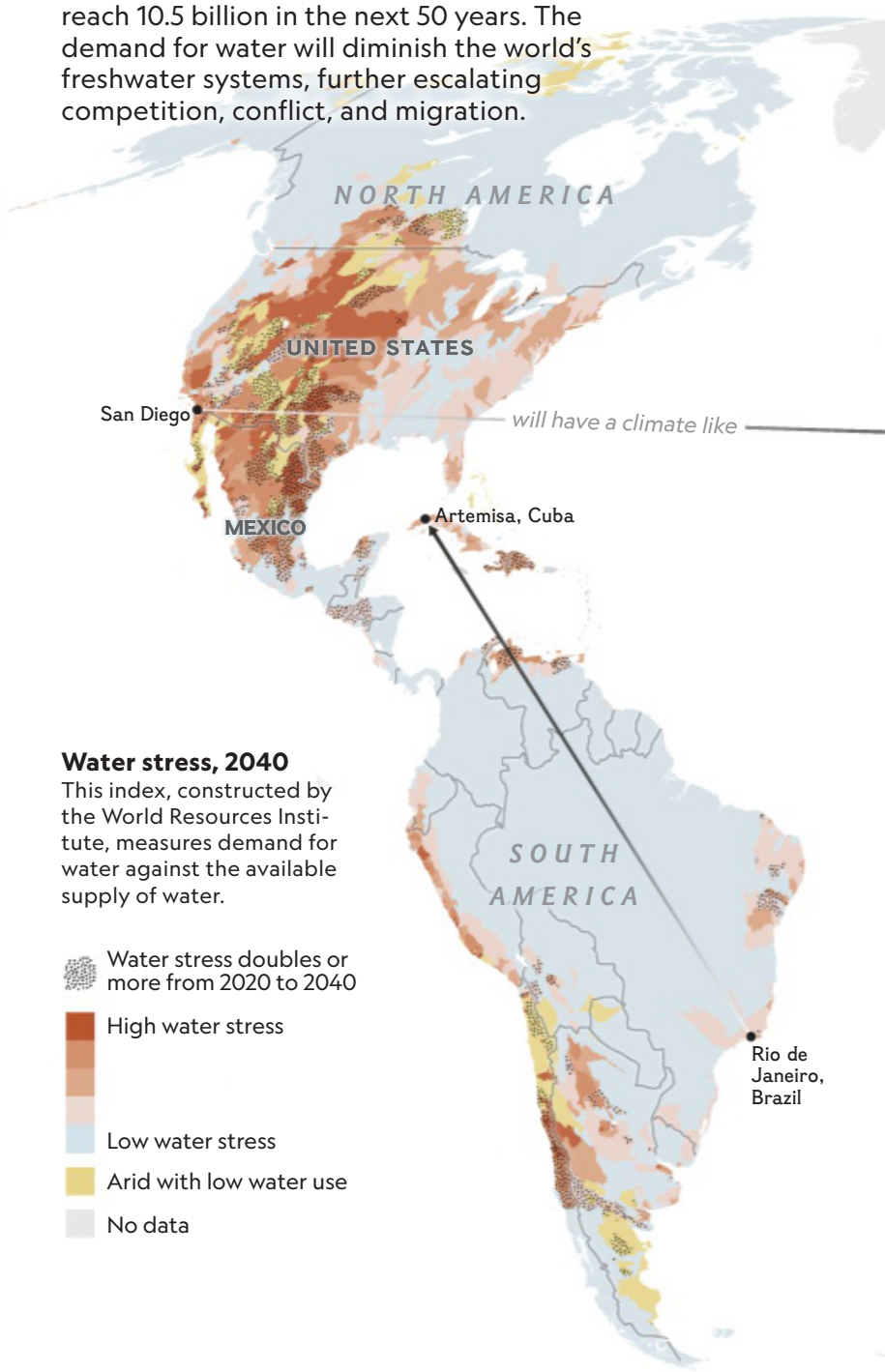
RISING WATER ANXIETY

In 50 years the climate profile of Manila will resemble that of present-day Idukki, in Kerala, India, where monsoon flooding in 2018 was responsible for more than 400 deaths and the displacement of millions. Today Manila is one of the fastest growing metropolitan areas on Earth, and one of the wettest. Typhoon Ketsana in 2009 covered Manila in almost 18 inches of rain in a single day—over a month's worth in only 12 hours. More than 200 people died. As the climate changes, wet places such as the tropics of Southeast Asia are likely to get much wetter. A hotter atmosphere holds more water, which means more rain falling more intensely during the rainy season. At the same time it aggravates drought, including outside of the tropics: Hotter air sucks more water out of plants and soil, drying the land. Too little water in vast swaths of the planet, too much in others—that's how climate change is rewriting the story of water on Earth.

This city in 2070	*will have a climate like*
SAN DIEGO, UNITED STATES	TAROUDANT, MOROCCO
RIO DE JANEIRO, BRAZIL	ARTEMISA, CUBA
CHENNAI, INDIA	AD DARB, SAUDI ARABIA

STRESSED FOR WATER

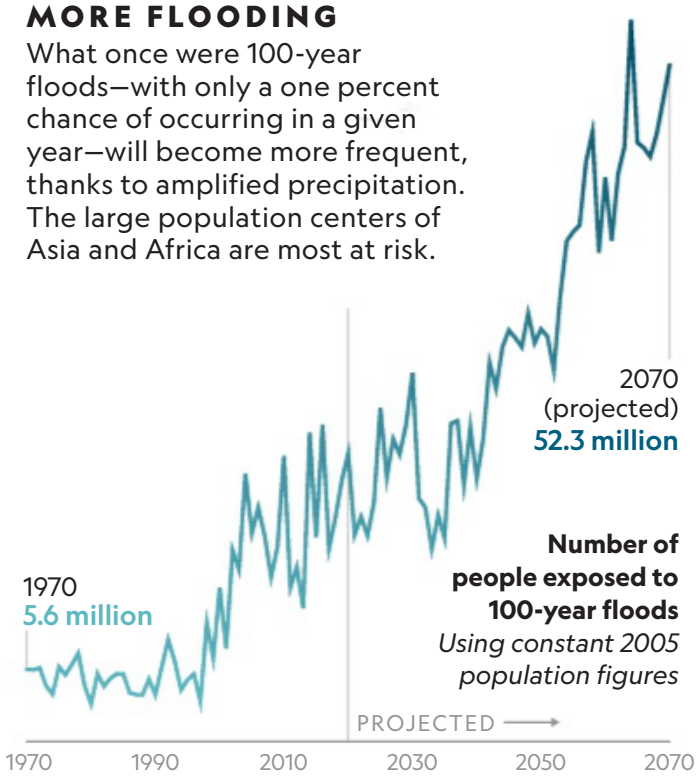
The global population is expected to reach 10.5 billion in the next 50 years. The demand for water will diminish the world's freshwater systems, further escalating competition, conflict, and migration.



Water stress, 2040
This index, constructed by the World Resources Institute, measures demand for water against the available supply of water.

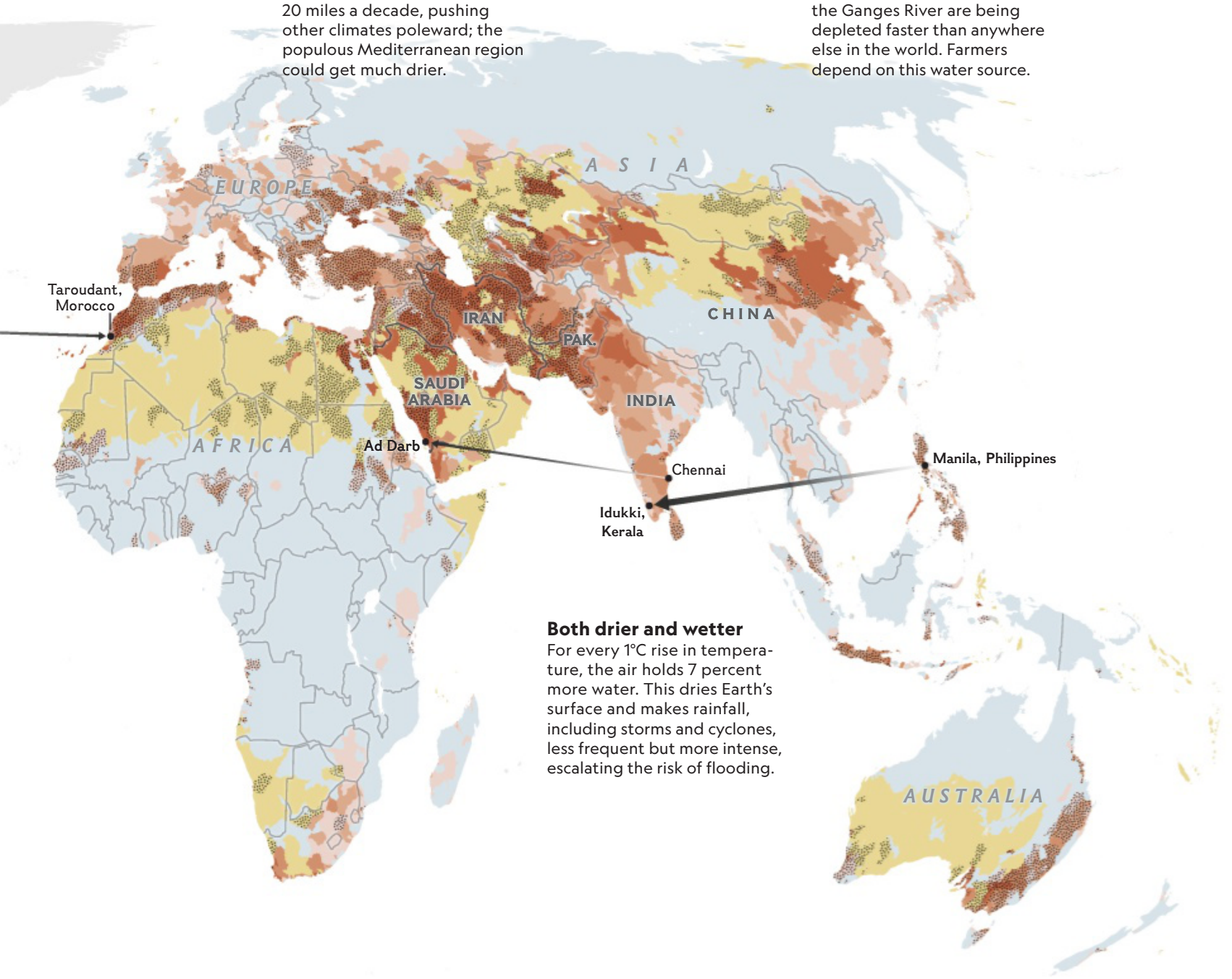
MORE FLOODING

What once were 100-year floods—with only a one percent chance of occurring in a given year—will become more frequent, thanks to amplified precipitation. The large population centers of Asia and Africa are most at risk.



Changing zones
Tropical zones are expanding 20 miles a decade, pushing other climates poleward; the populous Mediterranean region could get much drier.

Food shortages
In India the aquifers feeding the Ganges River are being depleted faster than anywhere else in the world. Farmers depend on this water source.

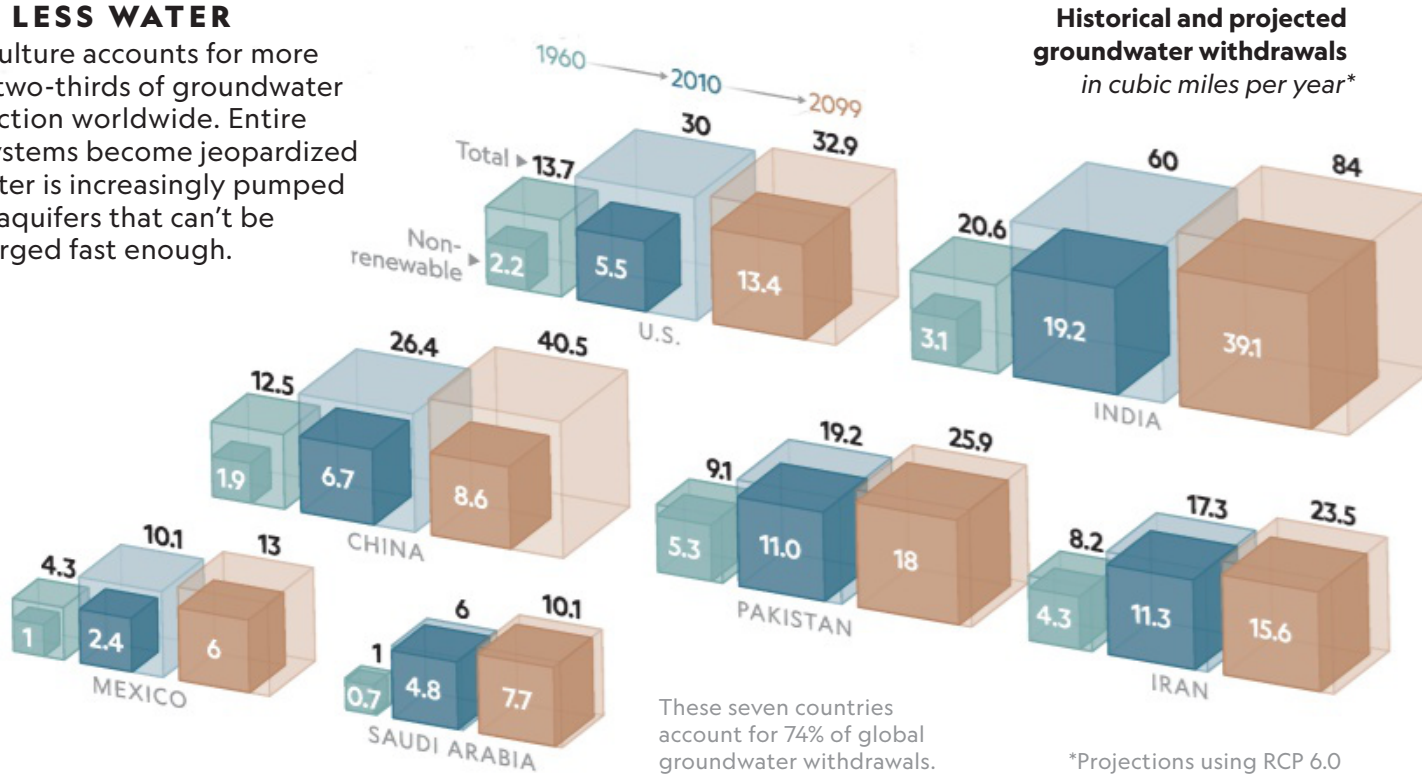


Both drier and wetter
For every 1°C rise in temperature, the air holds 7 percent more water. This dries Earth's surface and makes rainfall, including storms and cyclones, less frequent but more intense, escalating the risk of flooding.

BUT LESS WATER

Agriculture accounts for more than two-thirds of groundwater extraction worldwide. Entire ecosystems become jeopardized as water is increasingly pumped from aquifers that can't be recharged fast enough.

Historical and projected groundwater withdrawals
*in cubic miles per year**

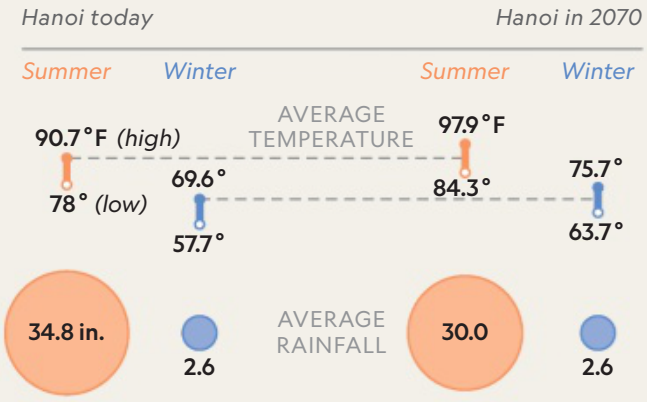


These seven countries account for 74% of global groundwater withdrawals.

*Projections using RCP 6.0

NAT CASE, INCASE, LLC. SOURCES: AQUEDUCT WATER RISK ATLAS, WORLD RESOURCES INSTITUTE; YUKIKO HIRABAYASHI, SHIBAURA INSTITUTE OF TECHNOLOGY; YOSHIHIDE WADA AND MARC FP BIERKENS, *ENVIRONMENTAL RESEARCH LETTERS,* OCTOBER 2, 2014

HANOI, VIETNAM, WILL HAVE A CLIMATE LIKE NOWHERE ON EARTH.



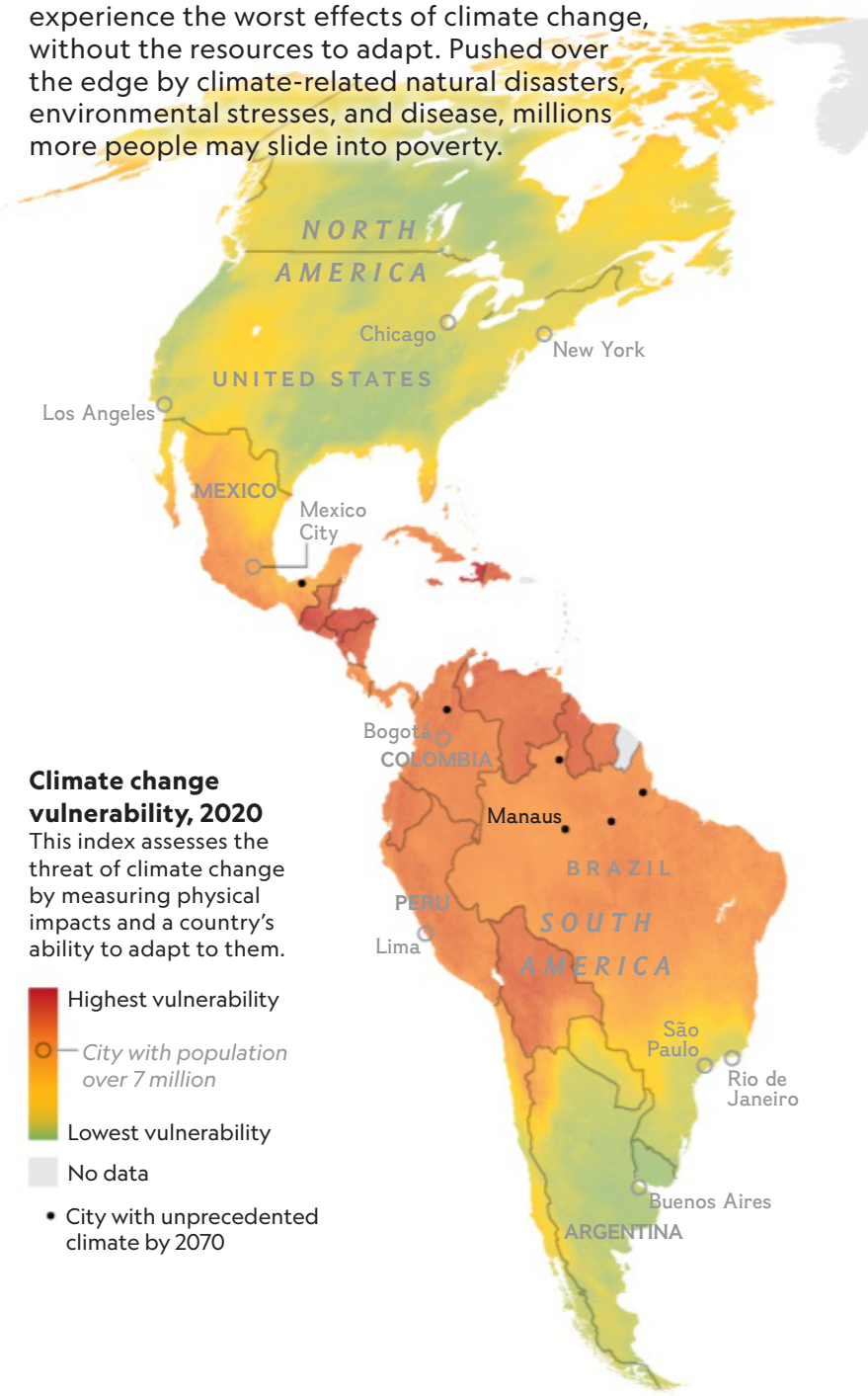
DAMAGE WILL BE UNEQUAL

There are some cities, such as Hanoi, where climates will enter uncharted territory by 2070. It's not just that Hanoi will get hotter—which it will, with average summer temperatures hovering close to a soupy 100°F. And it's not just that precipitation patterns will change as rainfall intensifies during the monsoon and other stormy periods. Some hazards can be traced to climate change, such as dangerous heat stress or flooding from extreme rains and sea-level rise. But millions living in cities worldwide will be increasingly vulnerable to less obvious problems. The risk of disease will climb as mosquito ranges expand. Conflicts will be more likely as populations are forced to move. Infrastructure, including housing, roads, and bridges, will crumble faster. And as we barrel into a future of unprecedented climates, it's almost certain that yet-to-be-identified vulnerabilities will emerge to put more stress on this fragile planet.

This city in 2070		*will have a climate like*
MANAUS, BRAZIL	▶	**NOWHERE ON EARTH TODAY**
LUXOR, EGYPT	▶	**NOWHERE ON EARTH TODAY**
DOHA, QATAR	▶	**NOWHERE ON EARTH TODAY**

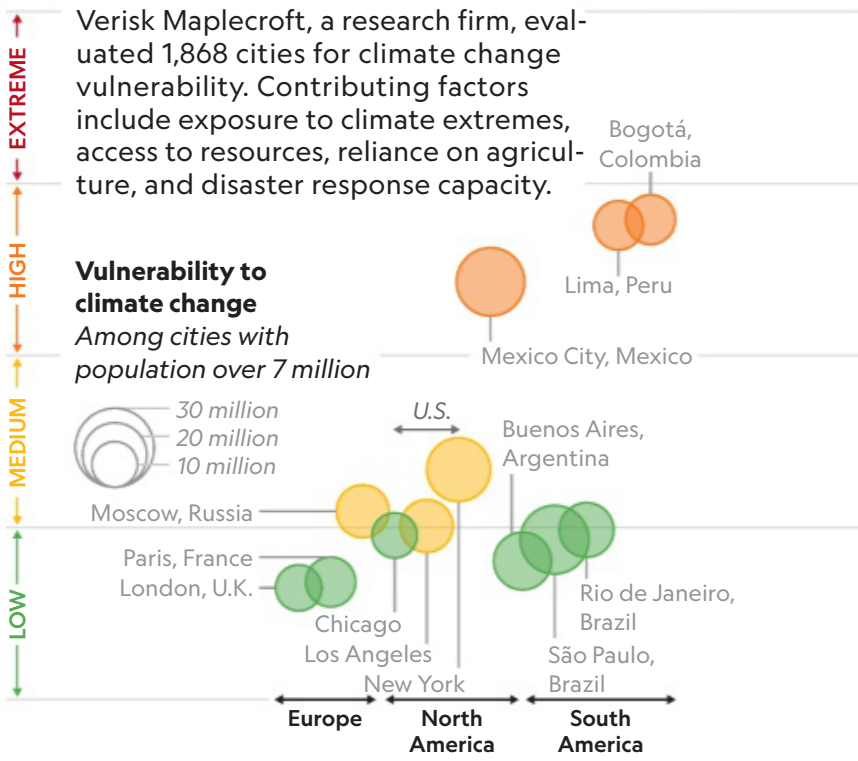
POOR MORE LIKELY TO SUFFER

Many of the poorest cities and countries will experience the worst effects of climate change, without the resources to adapt. Pushed over the edge by climate-related natural disasters, environmental stresses, and disease, millions more people may slide into poverty.



LARGE CITIES AT RISK

Verisk Maplecroft, a research firm, evaluated 1,868 cities for climate change vulnerability. Contributing factors include exposure to climate extremes, access to resources, reliance on agriculture, and disaster response capacity.



Safe havens
The most resilient cities are in countries that have less extreme climates and greater capacity to adapt, such as the U.K. and the Netherlands.

Diseases will spread
Before 1970, severe mosquito-borne dengue epidemics had occurred in only nine countries. The disease is found in over 125 countries today.

RUSSIA
Moscow
U.K.
London
EUROPE
Paris
FRANCE
ASIA
Istanbul
TURKEY
Beijing
Seoul, South Korea
CHINA
Xi'an
Tokyo
JAPAN
Shanghai
Chengdu
Baghdad, Iraq
Tehran
IRAN
Lahore
Cairo
EGYPT
Luxor
PAK.
Delhi
Riyadh
Kolkata
Doha, Qatar
SAUDI ARABIA
Karachi
INDIA
Hong Kong
Hanoi
AFRICA
SUDAN
Mumbai
Bengaluru
Bangkok, Thailand
VIETNAM
Manila, Philippines
NIGERIA
Lagos
Ho Chi Minh City
MALAYSIA
Kuala Lumpur
D.R. CONGO
Kinshasa
Jakarta
INDONESIA
Luanda
ANGOLA
AUSTRALIA

Out of this world
There are 67 cities that have no future analog. Their climate in 2070 is projected to be unprecedented—unlike any place on Earth today.

Low incomes, big danger
Richer cities can absorb growing populations more easily than poorer ones, which are less able to cope with demands on infrastructure and services.

Kinshasa, D.R. Congo
Manila, Philippines
Jakarta, Indonesia
Lagos, Nigeria
Baghdad, Iraq
Kuala Lumpur, Malaysia
Bangkok, Thailand
Ho Chi Minh City, Vietnam
Bengaluru
Riyadh, Saudi Arabia
Mumbai
Karachi, Pakistan
Luanda, Angola
Istanbul, Turkey
Tehran, Iran
Seoul, S. Korea
Foshan
Hong Kong
Guangzhou
Wuhan
Shanghai
Ahmadabad
Chennai
Hyderabad
Nanjing
Tianjin
Chengdu
Shenzhen
Lahore, Pakistan
Dongguan
Suzhou
Xi'an
Delhi
Surat
Kolkata
Dhaka, Bangladesh
Cairo, Egypt
Nagoya
Shenyang
Chongqing
Osaka
Hangzhou
Tokyo
Beijing
India
Japan
China

Africa's challenge
Africa has some of the fastest growing cities in the world; two-thirds of them are facing extreme risk from climate change.

Asia — **Africa**

SOURCE: VERISK MAPLECROFT